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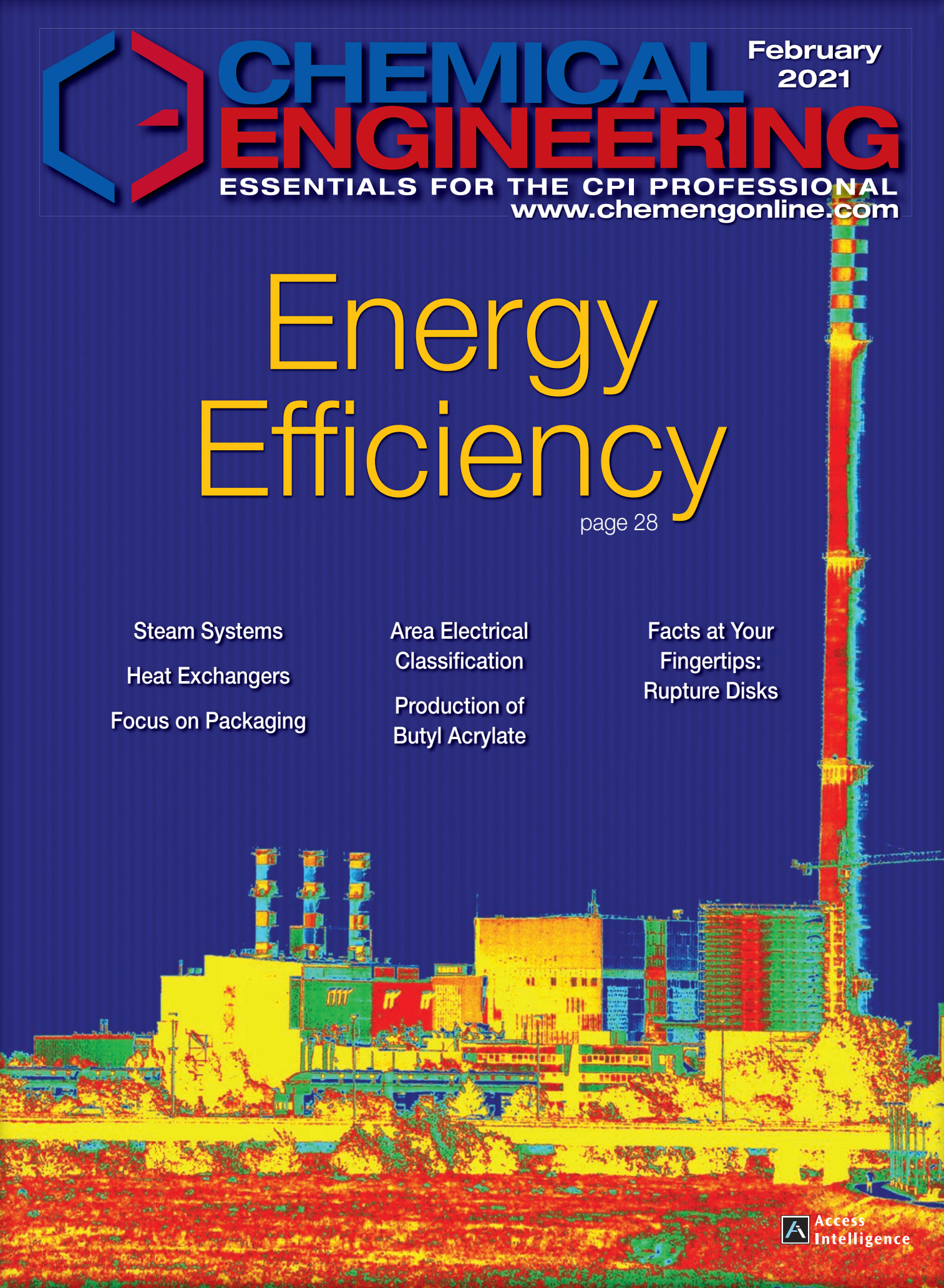

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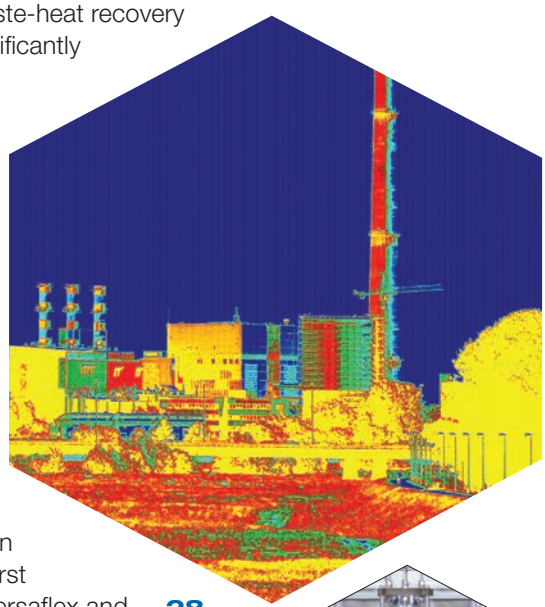
Cover Story



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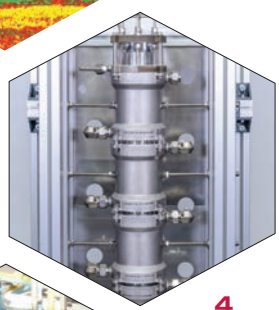

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Editor's Page

Addressing climate change

In a report[1] issued by the American Council for an Energy-Efficient Economy (ACEEE; www.aceee.org), one of the key summary points is that industrial decarbonization is essential to fighting climate change. The report states that the industrial sector accounts for more than 25% of energy-related U.S. emissions and the manufacturing subsector — which includes petroleum refining, food processing, and the production of chemicals, paper, cement, metals and other products — is the largest industrial user of energy with the largest share of emissions.

Climate-change goals

The chemical process industries (CPI) are indeed increasingly committing to climate-change-related goals with some ambitious targets. A number of companies including Dow (www.dow.com), DuPont (www.dupont.com), Eastman Chemical (www.eastman.com) and Total (www.total.com) are aiming to be carbon neutral by 2050.

The importance placed on climate-change goals is exemplified by Total's recent announcement to not renew its membership with the American Petroleum Institute (API) for 2021. In its announcement, Total says that it assesses industry associations according to their alignment with the company's climate positions, and that API's positions were "partially aligned," but that there were divergences. Total listed a number of its positions including: support for the objectives of the Paris Agreement; support of policies and initiatives that promote renewable energy; supporting the development of CO_2 capture and storage; as well as the need for carbon pricing; confidence that natural gas plays a key role in the energy transition; and the science-based position that the link between human activity and climate change is an established fact.

CPI companies have a multi-faceted approach to their decarbonization goals, including implementing renewable energy, carbon capture and storage strategies and through increasing energy efficiency. The previously mentioned ACEEE report says that "Energy efficiency should be the foundation of industrial decarbonization because it can immediately and simultaneously reduce emissions, cut costs and provide additional benefits…" As an example of energy efficiency strategies, Total has set a target of improving energy efficiency at its industrial facilities by 1% a year. The company says it has invested nearly $450 million to maximize energy efficiency in the Refining & Chemicals business segment, which accounts for 66% of Total's energy consumption.

In this issue

This month's cover story (Unlock the Energy Potential of Your Plant, pp. 28–33) explores specific ways to improve energy efficiency. It uses a steam-methane reforming process for hydrogen production as an example to illustrate principles that can be more widely applied. Our Newsfront (New Offerings Aid Heat Exchanger Design and Operations, pp. 12–15) offers insights and information on new products and tools related to heat transfer equipment that can influence industrial energy consumption and process efficiency.

We hope that you find these articles, as well as the many other sections in this issue, interesting and informative. ■

Dorothy Lozowski, Editorial Director

1. Transforming Industry: Paths to Industrial Decarbonization in the United States by Whitlock, Elliott and Rightor; May 2020.

Edited by:
Gerald Ondrey

AMMONIA CATALYST

Clariant Catalyst (Munich, Germany; www.clariant.com) and Casale SA (Lugano, Switzerland; www.casale.ch) have developed a new ammonia synthesis catalyst for sustainable CO_2 reduction. Based on Clariant's AmoMax 10 — a wüstite-based alternative to traditional magnetite-based catalysts — the AmoMax-Casale catalyst is said to have a significantly higher activity than previous catalysts. Developed using Clariant's catalyst expertise and Casale's ammonia converter-design know-how, AmoMax-Casale delivers an up to 30% higher efficiency factor, thanks to a larger active surface area than previous generations of AmoMax, thereby significantly lowering the energy consumption of an ammonia plant.

The catalyst's higher activity allows operation of the ammonia synthesis loop with considerably less pressure, which means the plant consumes less energy to produce ammonia, and hence generates less CO_2 emissions. The higher catalyst activity means higher conversion, so the plant will consume less energy for the recirculation of the process gas in the reactor loop.

The combination of a more active catalyst with the Casale design of converter internals makes the difference, says Clariant. A typical ammonia plant producing 1,600 ton/d, would potentially save $300,000/yr on energy costs. Furthermore, AmoMax-Casale is capable of increasing the ammonia production capacity by up to 5%, says Clariant.

(Continues on p. 6)

A microreactor for continuous formation of Grignard reagents

Today, synthetic routes to about 10% of the top 50 active pharmaceutical ingredients (APIs) include one or more Grignard reactions, which are used to form C–C bonds. Normally, the reaction is performed batch-wise in continuous stirred-tank reactors (CSTRs), with Grignard reagent added in limited amounts to restrict the generation of heat. This practice leads to long reaction times and increased formation of byproducts.

Now, researchers from the Fraunhofer Institute for Microengineering and Microsystems (IMM; Mainz, Germany; www.imm.fraunhofer.de) have eliminated these problems. "We've replaced the large CSTR with a flow reactor," explains research fellow Gabriele Menges-Flanagan. "This means we can use the full power of the reaction and still control the temperature wonderfully," she says. The advantages of switching from batch to a continuous process include a shorter reaction time (a few minutes), improved product purity and increased safety.

Inside the flow reactor, the reactant — usually an organic bromide or chloride — is pumped up through a bed of magnesium-metal shavings. An excess of Mg in the reactor ensures a fast activation of the reaction.


Fraunhofer

The reactor is a double-walled cylinder cooled by a continuous flow of oil, which quickly and efficiently removes the heat to control the temperature. Because both reactant and product flow through the reactor with short residence times, side reactions are inhibited.

A pilot plant, consisting of four reactor modules in series (photo), can process up to 20 L/h of reactant solution. Initial feasibility studies have already been carried out with industrial partners. The reactor is not only suitable for forming any conceivable type of Grignard reagent, but may also prove suitable for the synthesis of organometallic compounds of zinc. Indeed, researchers have already conducted such reactions at the laboratory scale.

Nanoscale uniformity of desalination membranes

Reverse-osmosis (RO) desalination membranes use a polyamide selective layer formed on a microporous support to separate water molecules from salts. Past efforts to characterize the polyamide membrane structure have been limited by the internal variability of the selective layer. Now, leveraging new capabilities in microscopy and modeling, a team of academic and industrial researchers has published a study describing key insights for the structure-property relationships of RO membranes. The study, published in a recent issue of the journal *Science*, resulted from a collaboration of researchers from the Pennsylvania State University (State College; www.psu.edu), University of Texas at Austin (www.utexas.edu), Iowa State University (Ames; www.iastate.edu), Dow Inc. (Midland, Mich.; www.dow.com) and Dupont Water Solutions (Edina, Minn.; www.dupont.com).

Using a specialized type of scanning transmission electron microscopy along with detailed computational modeling, the researchers were able to generate three-dimensional spatial information that reveals where the polymer is (and is not) concentrated within the membrane at the nanoscale. By constructing these nanoscale polyamide density maps of RO membranes, the researchers gained valuable insight into the relationship between density and membrane thickness in how water is transported.

It its analysis, the research team compared RO membranes manufactured under varying process conditions and concluded that "systematic control over nanoscale polyamide inhomogeneity" in desalination membranes is key to maximizing water permeability without sacrificing salt selectivity. While conventional modeling suggests that water passage should decrease with thicker membranes, that would be the case only if the membrane had a uniform thickness and density. A thicker membrane could result in improved water transport if the membrane was less dense, but more homogeneous, according to the study findings.

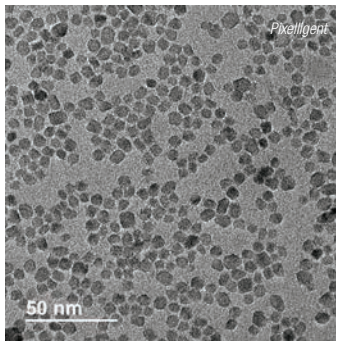
Metal-oxide nanocrystals have applications in lubrication and electronics displays

Pixelligent Technologies Inc. (Baltimore, Md.; www.pixelligent.com) has developed a process for making metal-oxide nanocrystaline materials that have found uses as additives in a variety of industrial lubricants, mixed- and augmented-reality (AR/MR) glasses, and various display technologies. The company's PixClearProcess results in dispersions of zirconium dioxide (ZrO_2) or titanium dioxide (TiO_2) nanocrystals capped with surface agents. The 5-nm crystals (photo) are grown from the bottom up via a proprietary method. The nanocrystal cores are coupled with functional groups on their surfaces, according to the application. The surface functional groups prevent the particles from aggregating, allowing for uniform dispersions in various media, including oils, solvents and resins.

"The PixClearProcess uses readily available raw materials and widely available equipment customized for Pixelligent to manufacture amounts of advanced nanocomposites in the range of several kilograms to multiple tons," says Richard Ming, Pixelligent global sales and marketing director. The metal-oxide nanoparticles increase the refractive index (RI) of the resin into which they are added and enable larger fields of view in AR/MR glasses. In display applications, the high-RI resins made by Pixelligent also improve light extraction and lower power consumption, along with allowing greater clarity and better operating efficiency, explains Ming.

For lubricant applications, Pixelligent product development manager Robert Wiacek says that at the nanoscale, the nanocrystals deposit as a 100-nm-thick "tribo-film" on the contact surface of steel equipment parts, which prevents wear on the moving parts. "The additives allow operators to use lower-viscosity oils, which can increase operating efficiency in motors, gearboxes, and other machinery," says Wiacek. Further, they form the protective film over a wide temperature range, and are transparent to visible light, so they do not change the color or appearance of the base oils themselves, he adds.

Pixelligent recently received a $1.8-million grant from the U.S. Department of Energy's Advanced Manufacturing Office to further develop the lubricant applications for the metal-oxide nanocrystaline materials, along with researchers at Argonne National Laboratory and the Carpick Research Group at the University of Pennsylvania, as well as well known industrial partners in the oil additives industry, including Lanxess Corp.



The catalyst has already proven its performance in its first industrial reference at an ammonia plant in the Americas. That plant was upgraded to a Casale three-bed interchanger using the AmoMax-Casale catalyst in late 2019, and is already reporting energy savings of 50,000 kcal/m.t., which translates to an expected reduction of $700,000/yr in costs, and 6.148 tons in CO_2 emissions.

SUPERCAPACITORS

Scientists at Tomsk Polytechnic University (TPU; Russia; www.tpu.ru) and the University of Lille (France) have synthesized a new material, based on reduced graphene oxide (rGO), that has potential applications in supercapacitors for energy storage devices. As described in a recent issue of *Electrochimica Acta*, the rGO was functionalized by aryne cycloaddition using "pseudocyclic iodoxoborole" (a derivative of hypervalent iodine) as an aryne source. The functionalized rGO (f-rGO) was found to have an interlayer spacing of 0.46 nm, compared to 0.38 nm for the unmodified rGO. As a result, the f-rGO showed a high specific capacitance of 297 F/g — much higher than 170 F/g for rGO. This means the f-rGO can store 1.7 times more energy that the unmodified rGO.

The research work was conducted with the support of the Russian Science Foundation.

SUSTAINABLE INSULATION

Researchers at the Institute of Natural Products Engineering at TU Dresden (Germany; www.tu-dresden.de) have developed an insulating material made from recycled paper for shipping temperature-sensitive foods and medicines. As part of a research and development project, the fundamentals were laid for the production of ecologically sustainable fresh-food shipping packaging and thus for an alternative to styrofoam and plastic packaging.

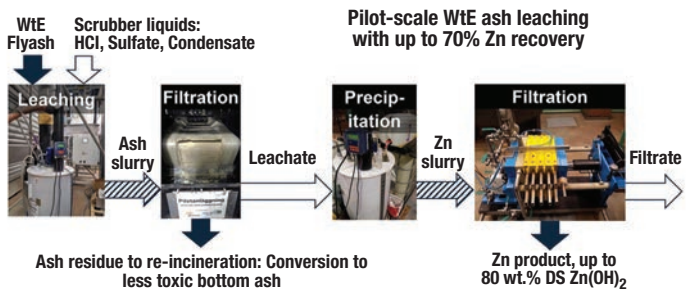
As part of the research project, waste paper was processed using a special drying technique to produce fiber-based insulating elements. Functional tests under practical conditions have shown that the insulating elements developed are capable of replacing conventional insulating materials, such as styrofoam, due to their low thermal conductivity. "Due to the low thermal conductivity and higher heat storage capacity of cellulose, the insulating properties of the sustainable fiber mats even surpass those of most other materials," says Thomas Schrinner, project coordinator at the chair of Wood Technology and Fiber Materials Engineering.

(Continues on p. 8)

Extracting zinc from flyash

In Sweden, incineration of household waste in waste-to-energy (WtE) plants is common, and generates around 250,000 metric tons (m.t.) of flyash every year. The rest of Europe accounts for around ten times that amount. Most of this waste is landfilled, but the ash often contains significant amounts of valuable metals, such as zinc. A process to extract such metals has been developed by researchers at Chalmers University of Technology (Gothenburg, Sweden; www.chalmers.se), and is described in a recent issue of *Waste Management.*

Chalmers



The Chalmers process is much simpler than the one developed in the 1990s at the Karlsruhe University of Technology (KIT; Germany), and generates a zinc concentrate instead of a purified metal. The concentrate can then be further refined in existing industrial metals-processing lines.

In the Chalmers process (photos), an acid wash is used to release zinc and other metal ions from the ash. The zinc is recovered from the leachate as zinc hydroxide using chemical precipitation, which can then be further refined using metal industry processes to generate high-purity zinc metal. The leached flyash can be re-incinerated in order to destroy toxic dioxins. During the pilot study, 75–150 kg/h of flyash from a Swedish WtE plant was mixed with scrubber liquids from the same fluegas-treatment system in a continuously stirred vessel. The resulting slurry was dewatered in a vacuum belt filter. Hydroxide precipitation of the resulting leachate, followed by filtration of the formed crystals in a membrane filter press, produced a filter cake with up to 80 wt.% zinc hydroxide.

Renova AB and Babcock & Wilcox Vølund AB (both Gothenburg, Sweden) are now building an ash-washing facility with zinc recycling in Gothenburg — an investment that is estimated to save hundreds of thousands of euros every year for the municipally owned waste-management company.

Printing sensors onto stickers

Advanced sensors are crucial to any predictive maintenance strategy, and often these sensors must be quickly installed into difficult-to-reach spaces. A novel nanomaterial technology enables predictive sensors that can be "printed" onto flexible stickers. These stickers can be easily attached to rotating or static equipment, including pumps, valves and pipelines. Developed by startup company Feelit (Haifa, Israel; http://feelit.tech), RetroFeel nano-ink sensors can measure process parameters in real time, including strain, temperature, humidity, vibration and pressure, providing remote sensing and critical alerts related to structural or operational anomalies. According to Feelit, the sensors and associated wireless-edge platform create a high-resolution "electric skin" for equipment, boasting a sensitivity that is reportedly 50 times greater than current sensing technologies on the market. The ability to simply glue the sensors to equipment enables a quicker, non-invasive startup without the need to halt production.

The Adhesive Technologies business of Henkel AG & Co. KGaA (Düsseldorf, Germany; www.henkel.com) recently announced its investment in Feelit's technology, and last year, the company collaborated with Merck KGaA (Darmstadt, Germany; www.merckgroup.com) for the first production test runs of the sensors. At a Merck production site, Feelit's sensors were installed on a diaphragm valve to predict diaphragm failure and prevent rupture and loss of chemical containment. Two pilot trials were completed with Feelit's sensors, and additional trials have been underway at other global manufacturing sites. The partnership with Henkel has expanded the sensors' reach for new monitoring applications in the oil-and-gas sector, says Feelit CEO Gady Konvalina. Feelit plans to significantly scale up its nanoprinting and sensor-fabrication capacities by 2024.

SUSTAINABLE FLOORING

Commercial flooring manufacturer Interface, Inc. (Atlanta, Ga.; www.interface.com) has created what is claimed to be the world's first carbon-negative carpet tile, thanks to process technology designed and supplied by industrial process solutions company IPCO AB (Sandviken, Sweden; www.ipco.com).

Interface CQuestBioX tiles feature a new type of backing that incorporates a high concentration of carbon-negative materials, including recycled tiles, scrap from in-house processes and selected bio-based additives.

Interface full CQuest backings line is produced on IPCO ScatterPro and ThermoPress systems. ScatterPro is a precision scattering technology used to deposit bulk materials in a consistent layer before being formed by pressure or heat (or both) in a ThermoPress system. A modular design allows multiple stages to be incorporated into one continuous process. Once the material has been scattered, it is heated to its melting point. A non-woven glass-fiber scrim is then laid on top and a second layer of recycled scrap deposited to impregnate the material as it passes through a second heating stage, creating the finished backing. Finally, the carpet upper is unwound and laminated to the backing.

CONCENTRATING BEER

Last month, Alfa Laval Group (Lund, Sweden; www.alfalaval.com) acquired Sandymount (Woburn, Mass.), a beverage-technology company with a patented membrane technology for concentrating beer. The technology, in combination with Alfa Laval's product range, will enable beer producers to deliver high-quality beer in concentrated form. The solution addresses the transportation inefficiencies in beer supply where beer remains one of the few water-laden products distributed as "mostly water" from producer to consumer, says Alfa Laval. The newly acquired company, with its founder and employees, will be integrated into the business unit Food Systems in the Food & Water Division.

Sandymount's patented reverse-osmosis (RO) membrane technology, tradenamed Revos, is a two-pass process for concentrating liquids containing small, neutrally charged molecules (like ethanol and aromatics). This means that any alcohol or aroma that does escape through the membranes in a first step of filtration is collected, put through a second pass and returned back to the first pass. In this way, the system as a whole is capable of retaining substantially all aromas and alcohol. Two-pass processes have been used for many years in seawater and industrial applications involving salts. Revos patents cover multi-pass or multi-step designs involving alcohols and aromas instead. Revos is a low-temperature, ultra-high pressure process, operating at over 120 bars (over 1,700 psi).

GRAPHENE HYBRID FOR SUPERCAPACITOR

Unlike batteries, supercapacitors can quickly store large amounts of energy and release it just as fast. However, one problem with supercapacitors has been their low energy density — typically one tenth of the energy density achieved in lithium batteries (up to 265 kW/h). Now, an international team, working with Roland Fischer, professor of Inorganic and Metal-Organic Chemistry at the Technical University Munich (TUM; Germany; www.tum.de), has developed

(Continues on p. 9)

A major project targets sustainable urea production

A consortium, led by the Netherlands Organization for Applied Scientific Research (TNO; The Hague; www.tno.nl), has received an exceptional grant of €21 million from the European Commission under the Horizon 2020 Framework Program to investigate and develop the potential of industrial symbiosis to convert residual gas emissions from steel production into resources for urea production.

Stamicarbon B.V. (Sittard, the Netherlands), MET Development S.p.A (Milan, Italy) and NextChem S.p.A. (Rome, Italy) — all subsidiaries of Maire Tecnimont Group (Rome, Italy; www.mairetecnimont.com) — participate in this consortium of steel, chemical and energy-transition companies, research institutions, universities and industrial partners active in both the steel and fertilizer industries.

The "Initiate" project (Innovative Industrial Transformation of the steel and chemical industries of Europe) will demonstrate a novel, symbiotic and circular process that transforms residual steel gases into resources for urea production. The core of this process is a modular carbon-capture utilization-and-storage (CCUS) technology, integrating the flexible conditioning of time-dependent and carbon-rich steel gases with the synthesis of ammonia.

Throughout the project, these innovative technologies and their optimal integrated operations will be proven in real industrial settings at the facilities of Swerim AB (Luleå, Sweden; www.swerim.se), advancing to technology readiness level. The successful demonstration will enable to move forward with the construction of a first-of-a-kind plant at the scale of 150 ton/d of urea, within a timeframe of 5 years.

Stamicarbon will be responsible for the commercial implementation plan. The main objective of the demonstration plant is to justify the viability and prove the capability to produce ammonia, while in the next phase the commercial implementation plan is focused to establish an industrial-scale Initiate plant reference for the production of urea.

Magnetic field cures adhesives faster with less energy

Conventional adhesives, such as epoxy, are designed to cure using moisture, heat and light. Curing is necessary to cross-link and bond the glue with the two secured surfaces as the glue crystallizes and hardens. Now, scientists from Nanyang Technological University (Singapore; www.ntu.edu.sg), led by professor Raju V. Ramanujan and associate professor Terry Steele, have developed a new adhesive that can be cured using a magnetic field.

The new adhesive is made by combining a commercially available epoxy adhesive with specially tailored oxide nanoparticles made from a chemical combination including manganese, zinc and iron. These nanoparticles are designed to heat up when electromagnetic energy is passed through them, activating the curing process. The temperature and rate of heating can be controlled, eliminating overheating and hotspot formation.

One gram of the new adhesive can be cured by a 200-W electromagnetic device in 5 min. In contrast, a conventional epoxy requires 1 h to cure in a traditional 2,000-W oven. "Our temperature-controlled magnetic nanoparticles are designed to be mixed with existing one-pot adhesive formulations, so many of the epoxy-based adhesives on the market could be converted into magnetic field-activated glue," says Ramanujan.

The new adhesive should be of considerable interest in the sports, medical, automotive and aerospace industries. The scientists have filed for a patent through NTUitive, the university's innovation and enterprise company.

Bacteria for wastewater treatment

Researchers from the National University of Singapore (www.nus.edu.sg), led by associate professor He Jianzhong, have found a new strain of bacterium called *Thauera sp.* strain SND5, which is capable of simultaneous nitrification and denitrification and phosphate removal from wastewater. The discovery has the potential to significantly reduce the operational costs and emission of greenhouse gases associated with traditional wastewater treatment methods.

Sewage contains nitrogen in ammonia and phosphorus in phosphates. Too much of either can pollute the environment and they must therefore be removed before the treated water can be released.

Most existing sewage treatment systems use separate reactors to remove nitrogen and phosphorus, which is a bulky and expensive process. Some existing systems use a single reactor, but they are inefficient because different bacteria in the same reactor will compete with one another, lowering the system's overall efficiency.

Also, some existing systems release nitrous oxide, a greenhouse gas. The NUS team's new bacterium converts the ammonia into harmless nitrogen gas instead. Compared with conventional nitrogen removal processes of nitrification and denitrification, the NUS team's use of the new bacterium can save about 62% of electricity due to its lower oxygen demand.

The researchers are now planning to test their process at a larger scale, and formulate a "soup" of several bacteria to boost SND5's performance even further. ■

a highly efficient supercapacitor based on a sustainable graphene-hybrid material.

The TUM researchers developed a graphene hybrid material that serves as the positive electrode in supercapacitors, and combined this with a proven negative electrode based on titanium and carbon. The new energy storage device not only attains an energy density of up to 73 Wh/kg, which is roughly equivalent to the energy density of a nickel-metal-hydride battery. It also performs much better than most other supercapacitors at a power density of 16 kW/kg, according to TUM.

The researchers combined the novel positive electrode of the storage unit (with chemically modified graphene) with a nano-structured metal organic framework (MOF). This graphene hybrid has a large specific surface (up to 900 m^2/g) and controllable pore sizes, as well as a high electrical conductivity. When used in a cell, the TUM material retained around 90% capacity after 10,000 cycles. For comparison, the useful life of a "classic" lithium accumulator is around 5,000 cycles, says TUM.

The research — performed in collaboration with scientists from India, Australia, Spain, the Czech Republic and the U.S. — was published in a recent issue *Advanced Materials.*

FLAT SILICON COMPOUNDS

Researchers at the University of Bonn (Germany; www.uni-bonn.de), led by professor Alexander C. Filippou of the Institute for Inorganic Chemistry, have constructed silicon-containing molecules in which the four ligands do not form a tetrahedron, but a distorted square — a trapezoid. They lie in one plane together with the silicon. The influence of the unusual structure on the properties of Si — an important element for the electronics industry — is completely unclear at the moment. ❐

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Plant Watch

Linde to build world's largest PEM electrolyzer in Germany

January 14, 2021 — Linde plc (Guildford, U.K.; www.linde.com) will build, own and operate the world's largest proton-exchange membrane (PEM) electrolyzer plant at the Leuna Chemical Complex in Germany. The new 24-MW electrolyzer will produce green hydrogen to supply Linde's industrial customers through an existing pipeline network. The plant is due to start production in the second half of 2022.

Asahi Kasei to build second production plant for microcrystalline cellulose

January 14, 2021 — Asahi Kasei Corp. (Tokyo, Japan; www.asahi-kasei.co.jp) announced that its Specialty Solutions business unit will build a second plant for microcrystalline cellulose at its Mizushima Works site in Kurashiki, Okayama, Japan. This investment of ¥13 billion ($126 million) will double the company's production capacity for these products. Asahi Kasei expects groundbreaking for the new site to take place in September 2021, with completion of the project planned in 2023.

Total and Engie to develop France's largest green hydrogen site

January 13, 2021 — Total SE (Paris, France; www.total.com) and Engie S.A. (Courbevoie, France; www.engie.com) have signed a cooperation agreement to design, develop, build and operate the Masshylia project, France's largest renewable-hydrogen production site. Powered by solar farms with a total capacity of more than 100 MW, the 40-MW electrolyzer will produce 5 metric tons (m.t.) of green hydrogen per day to meet the needs of the biofuel production process at Total's La Mède biorefinery.

LanzaTech and SkyNRG to build Europe's first ethanol-to-SAF plant

January 13, 2021 — The Flite consortium, led by SkyNRG B.V. (Amsterdam, the Netherlands; www.skynrg.com) and with LanzaTech, Inc. (Skokie, Ill.; www.lanzatech.com) as the technology provider, will build a first-of-its-kind facility in Europe, which will convert waste-based ethanol to sustainable aviation fuel (SAF) at a scale of over 30,000 metric tons per year (m.t./yr). The project recently received €20 million in grant funding.

Celanese plans to build a liquid-crystal polymerization plant in China

January 12, 2021 — Celanese Corp. (Dallas, Tex.; www.celanese.com) intends to build a world-scale, multi-phase liquid-crystal-polymer (LCP) polymerization plant in China. Site selection is underway, and the total scope of the investment is intended to support approximately 20,000 m.t./yr of LCP production with the first phase of the project expected to come online in 2024. Celanese currently has LCP polymerization capability in Shelby, N.C.

Kemira completes first phase of capacity expansion for water-treatment chemicals

January 5, 2021 — Kemira Oyj (Helsinki, Finland; www.kemira.com) completed the first phase of a two-step capacity expansion for water-treatment chemicals in Ellesmere Port, U.K. Following the expansion, the output of the aluminum-based product line in Ellesmere Port was increased by more than 30,000 m.t./yr.

Neste successfully processes liquefied plastic waste at industrial scale

December 29, 2020 — Neste Corp. (Espoo, Finland; www.neste.com) successfully processed 400 m.t. of liquefied plastic waste at its refining complex in Finland. This was the first time that Neste processed liquefied waste plastic at an industrial scale. During the run, packaging and mixed-waste plastics were upgraded into high-quality recycled feedstock for petrochemical industry uses. Neste aims to gradually increase its volumes of liquefied waste-plastic processing.

Mitsubishi Chemical to build plant for carbon-fiber-reinforced thermoplastics

December 29, 2020 — Mitsubishi Chemical Corp. (MCC; Tokyo; www.m-chemical.co.jp) plans to establish a new pilot facility for carbon-fiber-reinforced thermoplastic (CFRTP). The facility will be located in Fukui Prefecture, Japan and is scheduled to start operation by the end of 2021.

Sumitomo Chemical exploring combined PDH production scheme in Singapore

December 29, 2020 — Sumitomo Chemical Co. (Tokyo, Japan; www.sumitomo-chem.co.jp) has begun exploring a possible combination of a propane dehydrogenation (PDH) technology, which converts propane gas into propylene, with another technology that efficiently synthesizes methanol from hydrogen and carbon dioxide, both of which are byproducts from the PDH process. This initiative is under consideration at Sumitomo Chemical's petrochemical complex in Singapore.

Gevo announces plans for potential renewable-fuels plant in South Dakota

December 29, 2020 — Gevo, Inc. (Englewood, Colo.; www.gevo.com) has optioned the right to purchase approximately 239 acres of land near Lake Preston, S.D. The production facility planned for Lake Preston is projected to produce about 45 million gal/yr collectively of jet fuel and renewable gasoline products.

Mergers & Acquisitions

Sulzer to acquire Nordic Water for $144 million

January 12, 2021 — Sulzer AG (Winterthur, Switzerland; www.sulzer.com) has signed a binding agreement to acquire Nordic Water (Gothenburg, Sweden) for a purchase price of SEK1.2 billion (around $144 million). Nordic Water is a leading provider of screening, sedimentation and filtration solutions for municipal and industrial water and wastewater applications.

PPG acquires coatings specialists Versaflex and Wörwag

January 12, 2021 — PPG Inc. (Pittsburgh, Pa.; www.ppg.com) has reached a definitive agreement to acquire Wörwag (Stuttgart, Germany; www.woerwag.com), a global manufacturer of coatings for industrial and automotive applications. Wörwag operates locations in Germany, the U.S., China, South Africa, Mexico, Spain, Switzerland and Poland. PPG is also acquiring The VersaFlex Family of Companies (Kansas City, Mo.; www.versaflex.com) VersaFlex is a manufacturer specializing in polyurea, epoxy, polyurethanes and geotechnical and insulation foams.

Air Liquide forms helium-refrigeration JV in China

January 11, 2021 — Air Liquide S.A. (Paris; www.airliquide.com) and Hefei Institutes of Physical Science of the Chinese Academy of Science (HFIPS) signed an agreement to establish a joint venture (JV) focused on the development and manufacture of helium refrigeration systems, supporting the evolution of large scientific experiments in China.

Lanxess to acquire French disinfection specialist Theseo

January 11, 2021 — Lanxess AG (Cologne, Germany; www.lanxess.com) intends to acquire the Theseo Group (Laval, France), a leading manufacturer of disinfection and hygiene solutions in Europe and Latin America. The envisaged acquisition has an enterprise value of approximately €70 million, and closing is expected in mid-2021.

Solvay to sell amphoteric surfactant business

January 5, 2021 — Solvay S.A. (Brussels, Belgium; www.solvay.com) agreed to sell its North American and European amphoteric-surfactant business to private equity firm OpenGate Capital. The sale includes the three main production sites supporting the amphoteric product lines located in University Park, Illinois, Genthin, Germany and Halifax, U.K., as well as a tolling business in Turkey.

Metso Outotec divests its aluminum business

December 29, 2020 — Metso Outotec Corp. (Helsinki, Finland; www.mogroup.com) has signed an agreement to sell its aluminum business to REEL International, SAS (Lyon, France). The business to be divested comprises green anode plants, anode rodshops and casthouses used in aluminum smelters, as well as related equipment and services. ■

New Offerings Aid Heat Exchanger Design and Operations

New offerings, including software products, consulting services, research insights and design tools, provide support for improving heat exchanger design and operation

Because they are critical pieces of equipment across virtually all sectors of the chemical process industries (CPI), heat exchangers and auxiliary systems have an out-sized influence on industrial energy consumption and process efficiency. Well designed, well maintained, well operated heat exchangers can increase product output while improving energy efficiency and safety (Figure 1). A number of new software products, online tools and consulting services have become available to support plants using heat exchanger equipment.

FIGURE 1. An improved sustainability profile is among the main drivers for heat exchanger design and operation, and addressing fouling is a critical aspect

Push for sustainability

Heating and cooling unit operations represent an area of particular interest for sustainability initiatives because of the thermal energy inputs. "One of the main issues for heat exchangers is sustainability," says Tom Lestina, senior vice president for engineering at Heat Transfer Research Inc. (HTRI; Navasota, Tex.; www.htri.net). "If you get the heat exchanger design right, you can dramatically increase the environmental benefits, both in terms of reducing the energy required in the process and generating more product with the same amount of energy," he explains. Increasing heat-transfer between hot and cold fluid streams, mitigating fouling and increasing uptime are all major strategies that can help improve the sustainability profile of a heat transfer system.

HTRI is engaged in a multi-pronged research and development effort, using 11 test rigs at its technology center in Navasota, Texas (Figure 2), along with advanced computing capability and software development to identify pathways to improvements in a systematic and scientific way. Many of the proprietary projects, carried out on behalf of industrial clients, have to do with higher-effectiveness heat exchangers that improve a process' sustainability profile. One prominent aspect of this is addressing a perpetual challenge for heat exchanger operation — fouling (deposits from sedimentation, corrosion or precipitation or chemical reaction that form on heat transfer surfaces, reducing the heat transfer efficiency). "In process heat transfer, better sustainability requires mitigation of fouling in the exchanger," Lestina states, especially in the petrochemicals industry. "This means allowing better design, better monitoring and more efficient cleaning of the fouling. We're looking at all types of coatings and how they can reduce fouling, and also how they can improve thermal performance."

The emphasis on sustainability is echoed by Ann Baymont, the welded product portfolio manager at Alfa Laval AB (Lund, Sweden; www.alfalaval.com). "Over the past 10–15 years, there has been a pronounced trend toward the use of more compact heat exchangers," Baymont says, "and in the past few years, it has really become a race for efficiency, where users are looking for ways to squeeze more output from the equipment they have, and also realize cost savings and lower emissions from their processes."

In addition to research insights, HTRI also offers software tools for

FIGURE 2. This air-cooled unit is among the 11 research rigs in place at HTRI's facility in Texas

users trying to boost performance. In late 2020, HTRI launched Edgeview, a new, trademarked software tool that analyzes heat exchanger performance across a range of operating data. "Edgeview facilitates analysis and troubleshooting for heat exchangers," Lestina says. "The system more quickly runs data from the plant historian through the software to determine corrective action."

HTRI also released a new updated version (Version 5.0) of its SmartPM software, which can monitor the performance of heat exchanger networks and help optimize cleaning schedules. Lestina says recent developments facilitate two-way, real-time data exchange with plant data systems to streamline performance assessment."

Training can also be an essential part of ensuring excellent design and furthering sustainability goals. HTRI recently launched an e-learning initiative to offer industry engineers online courses to improve their knowledge of process heat exchangers and thermal performance assessment. The first course, released late last year, is titled "Air-cooled Heat Exchanger Technology." The course provides an introduction to the design and performance of API-661-type air coolers, HTRI says.

Democratizing design

Heat-exchanger design improvements could also get a boost from a new company launched in late 2020. The company, known as AHED (Advanced Heat Exchanger Design; www.hrs-ahed.com), is offering heat exchanger design software intended to be more accessible and affordable to a wider cohort of CPI professionals. The new company was spun out of HRS Heat Exchangers Ltd. (Watford, U.K.; www.hrs-heatexchangers.com). AHED general manager Arnold Kleijn explains that the company's new software offering is based on design programs that have been used internally at HRS for the previous several years (Figure 3).

The result is a cloud-based program intended to meet the demand for heat-exchange design software that goes beyond specialist manufacturers. Examples include construction contractors who design their own equipment, but outsource manufacturing, or system integrators who want to check designs as part of a wider process, Kleijn explains, as well as academic researchers and students.

"There are already existing heat-exchange design programs that are good products, but they tend to be very expensive and require users to pay one price for differing amounts of usage. We are offering a product based on 40 years of design experience that has much of the functionality and information as existing programs, but for a significantly lower price," says Kleijn.

"AHED has been specifically designed around a modular, cloud-based architecture, with a range of licensing options, so that users can select the amount of functionality and the tools they require, from the essentials of heat exchanger design and the accompanying calculations, to options such as more heat exchanger types (like multi-pass and triple tube designs), batch calculations, fluid databases and project sharing tools," Kleijn explains.

The program's cloud-based architecture allows for automatic software updates and easy sharing among project team members at different sites, as well as with sales agents and other interested parties. "We also offer the ability to get engineering services, such as design checking and and training, Kleijn adds.

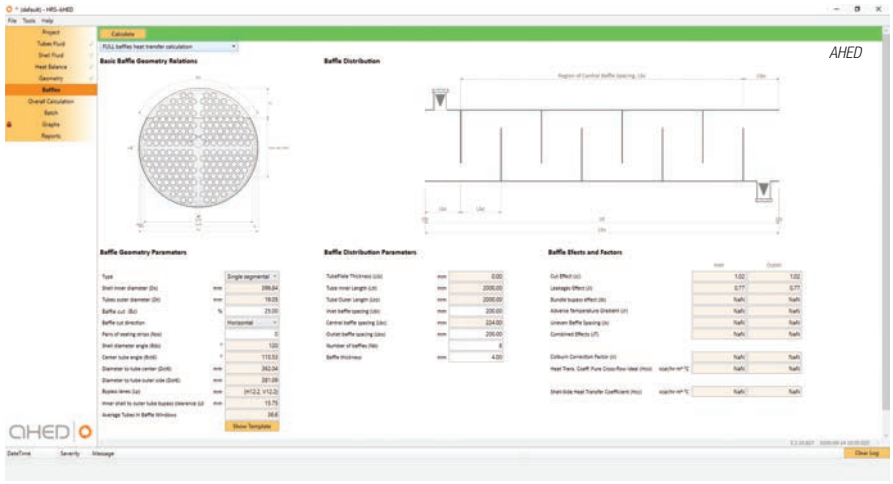


FIGURE 3. A newly available cloud-based software program for heat-exchanger design is based on software previously used internally at HRS

Features include a database of physical properties for over 2,000 fluids, information on complex mixtures and non-Newtonian fluids and both thermal and mechanical design, as well as easy data export and vibration analysis. The information is backed up by peer-reviewed research literature, Kleijn says. With inputs such as service fluids, tube geometry and heat parameters, the software returns necessary calculations with graphical representations of heat-transfer rates under different conditions.

Free trial licenses are now available for the AHED software.

Technology selection

Another recent offering to help process engineers with heat exchanger selection is Alfa Laval's HEXpert, an interactive online tool (www.alfalaval.com/hexpert) that provides guidance to match the demands of a particular process with available technology. "Users can enter basic information about their process, including what function the heat exchanger will serve, what are the design pressure and temperature, what types of process media are involved, and so on," Baymont explains, "and the online tool will return heat-exchanger technology solutions that match those process parameters."

One new heat transfer technology that could show up in the selection tool as an option for some users is a new model in Alfa Laval's Compabloc product range (Figure 4). Launched last year and known as Compabloc+, the model is constructed with a patented sealing technology, which increases the pressures that can be accommodated with block-type heat exchangers. "While the original Compabloc equipment could handle pressures up to 40 bars, the new Compabloc+ allows pressures up to 60 bars," Baymont remarks.

In addition to technology selection, Baymont says the company is working on expanding the online tool to include heat-exchanger sizing as well. "With heat exchange technologies that have been available for a long time, there are references that users can find in books to calculate sizes for equipment," Baymont says, but for newer types of heat exchangers, that information is not generally available. Forthcoming online sizing tools will help users be more autonomous as they size their heat transfer equipment, Baymont adds.

Steam HX operation

Another avenue where users of heat exchangers can get design and operations help is through consulting services. For sites that use steam heat exchangers and steam systems, TLV Corp. (Charlotte, N.C.; www.tlv.com) offers a service that provides a no-charge, individual application design review of heat exchange equipment (reboilers, heat exchangers, evaporators, vaporizers, coils, kettles and so on) during the design or revamp stage. "The review is called a coil drain application (CDA), which consolidates design information onto a single application form," explains Jim Risko, TLV USA president.

TLV's Consulting & Engineering Services (CES) team uses the CDA to apply best practice principles into the design recommendations, and the "recipient receives a best practice recommendation based on TLV experience in mitigating onsite issues — sometimes resulting from inappropriate designs from other parties, and other times due to process changes," Risko says.

TLV has been involved in the integration of steam heat exchangers and steam systems into wider processes, and has developed insights on how to optimize those systems. TLV consultants assess steam balance and supply to specific heat exchangers to help plants optimize steam use, as well as the recovery of condensate. Focus is to improve productivity, increase energy efficiency, mitigate potential failures of the heat exchanger and related control systems, increase uptime and minimize safety risk, says Jon Walter, TLV business development manager.

Among the insights that has taken shape over the past few years is a recognition that effectively removing condensate from the steam space of steam-driven heat exchangers can help reduce corrosion and fouling in the heat exchanger, as well as improve process productivity by improving the responsiveness of the heat exchanger to changes in loads. "Since TLV is a steam specialist company, we primarily focus on optimizing the quality of the heating utility (steam) supply and optimizing the drainage of condensate from the heating space," says Justin McFarland, TLV engineering manager. "When there is a focus on proper steam system and condensate system design, we often see a tremendous positive impact on safety, reliability, and environmental factors, especially as it relates to the larger process or a particular unit," he says.

Heat exchanger reliability and process stability are key objectives of plant sites across many CPI sectors. Reliability and stability involve avoiding bottlenecks, Risko points

out. "Among the key issues that can cause disruption include either stall (reduction or stoppage of steam condensate flow from the heat exchanger) or improper balancing – even if just from a simple level-pot balance line," he says. Risko will be addressing these issues in a talk at the upcoming AIChE Distillation Symposium in April 2021.

Bottlenecks in the steam heat exchanger system restrict optimal performance, but they can often be anticipated and mitigated during design by using proven best practices. For example, TLV has identified the proper drainage of condensate from steam heat-exchange equipment as an area of focus for optimizing steam heat exchanger performance. TLV has found that many corrosion and other issues can be mitigated not necessarily with a change in maintenance, but with changes in how a heat exchanger drains condensate from the steam space. "Heating control configurations that utilize level control often have issues with tube bundle corrosion and fouling, and require frequent maintenance, says Tracy Snow, senior consultant in TLV's Consulting and Engineering Services division. "Similarly, low process temperature requirements may mean low steam supply pressures, which can also lead to backup of condensate and subsequent tube bundle corrosion and fouling."

Utilizing a control configuration such as inlet steam pressure/flow control and a steam trap to drain the heat exchanger instead of level control, or utilizing TLV's PowerTrap system when steam supply pressures drop below the return pressure can help to mitigate the issues that often lead to corrosion," Snow says.

Heat exchanger installation

In a timely and helpful development for heat exchanger users, relative to the current travel and other challenges associated with the ongoing COVID-19 pandemic, HRS Inc. announced a method to allow for remote commissioning of heat exchange equipment. One case where this was put into practice involved a natural food manufacturer in the U.S. that was installing an aseptic multitube heat exchanger, and associated pumps and controls systems, for sterilizing a fermentation medium.

FIGURE 4. Alfa Laval launched a new model in its Compabloc product line that can handle higher pressures than previous models

After the HRS equipment was delivered and installed by the end-user, the company needed a method for engineers to complete the commissioning and troubleshooting process without actually involving international travel. As HRS explains, all HRS systems can, with the user's agreement, be fitted with a remote monitoring and telemetry system using either an ethernet connection (as is the case with this project) or an integrated data SIM in the equipment.

"This enabled a dedicated project engineer to manage the commissioning from Murcia (in Spain) along with a system programmer," HRS says. The exercise, performed while accounting for a six-hour time-zone difference, "allowed the system software to be adjusted as necessary while the sterilizer was operating," HRS says. The remote access system was backed up by regular dialogue using online conferencing software, and the set-up and commissioning process was completed in just four weeks.

In another installation-related development, HRS also has released modular skid-mounted versions of some of its systems for a wide range of applications, including heating and cooling. A modular process skid is a processing system contained within a frame, making it easier to transport and install. Individual skids can contain anything from a single heat exchanger and ancillaries to complete and complex systems where the skid typically contains process equipment, controls and monitoring equipment, and ancillaries.

Benefits include ease of installation, small footprint and quality construction. Skids can be supplied in multiple sizes, from a typical 48 in. × 40-in. pallet, up to a full 8-ft × 40-ft shipping container. One recent example was a skid-mounted pasteurization system for orange juice.

New manufacturing facility

Alfa Laval's brazed heat exchanger production is moving into a new, purpose-built factory in San Bonifacio, Italy. Manufacturing has already begun at the advanced new facility, and preparations are being made for research and customer training on site. The new factory is designed for efficiency, the company says, and includes new manufacturing advances on the production floor and a digitalized warehouse management system to oversee the flow of materials and goods. In addition, the facility is equipped with a rooftop solar-power system capable of generating 1 MW of power for the site. The factory features improvements to loading bays, forklift-free internal logistics and other physical improvements. ■

Scott Jenkins

Focus on Packaging

TAB Industries

Orbital wrapper for safe transport of drums and barrels

Orbital stretch-wrapping machines in the Wrapper Tornado line secure steel, plastic, fiberboard and other drums and barrels to pallets (photo) to prevent sliding, shifting and tumbling in transit and storage. Eliminating the need for cumbersome banding, cinching and strapping, the patent-pending Wrapper Tornado wraps stretch film 360 deg around and under the pallet and over the top of the drums and barrels in multiple layers in seconds to create a tight, durable wrap that promotes safe arrival without scratches, dents, dings or spills. The semi-automatic Wrapper Tornado allows the palletized containers to be safely wrapped while raised on a forklift at the press of a button or by the forklift driver alone using remote control from their seat (optional). — *TAB Industries, LLC, Reading Pa.*

www.tabwrapper.com

Dinnissen Process Technology

Combining high-care filling with low-care palletizing

This new technology for filling big bags in high-care zones combines high-care filling with low-care palletizing. The system (photo) meets all requirements for high-care, medium-care and low-care filling, processing, sealing and transporting big bags. Moreover, this solution is equipped with a fully automatic palletizing station. The filling of big bags takes place in a closed filling process. Compaction and weighing both take place in one position, during filling. Furthermore, no hydraulics are used in the high-care zone. To keep the oxygen level below 0.5%, stretching spout technology and triple sealing are used. The entire system of high-care filling and low-care palletizing is designed, built and tested in-house. — *Dinnissen Process Technology, Sevenum, the Netherlands*

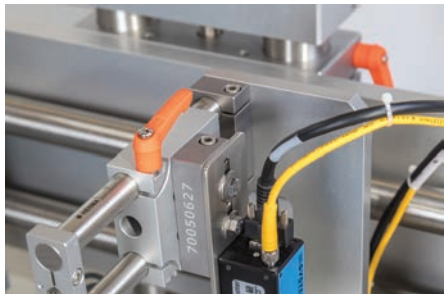
www.dinnissen.eu

TurboFil Packaging Machines

Cap bottles gently and precisely with this capper

This company has introduced a servo-driven chuck capper offering precision torque and gentle handling without costly bottle-change parts. The Acrobat Chuck Capper (photo) is available in single- and dual-head formats capable of processing up to 90 units per minute. The new capper's proprietary technology and parallel belts eliminate the expense of making and storing change parts for most bottles; for the smallest bottles, only minor, inexpensive parts are needed for fast, easy changeover. Regardless, the Acrobat's servo motor operation provides accurate, repeatable torque control and, for difficult threads, also can perform counterclockwise thread seating. — *TurboFil Packaging Machines LLC, Mt. Vernon, N.Y.*

www.turbofil.com



Herma US

This labeling machine is FDA compliant

Later this year, this company plans to introduce a new ultra-compact labeling machine at Healthcare Packaging Expo (Las Vegas, Nevada; September 23–25, 2021). Designed to meet pharmaceutical-sector demands for a fully U.S. Food and Drug Admin. (FDA)-compliant labeler in a very compact footprint, the 211 HC Wrap-around Labeler (photo) is a semi-automatic unit seen as particularly helpful in the transition from clinical trials to full production, as well as for the smaller-batch manufacturing typically found in biopharmaceuticals settings. The 211 HC is suitable for labeling a wide range of cylindrical products, including syringes, tubes, glass vials and ampoules. Capable of applying approximately 30 labels per min, the system can handle webs as wide as 80 mm, and products ranging in diameter from 10 to 120 mm. — *Herma US Inc., Fairfield, N.J.*

www.herma.us

Feed canisters quickly with this machine

The CDFI Canister Feeder (photo, p. 17) is an intermittent-motion machine for inserting desiccants or oxygen absorbers into a broad range of bottles, jars, tubes and vials. The latest addition to the company's Impact

series of packaging equipment, the compact, low-cost unit can accommodate up to 100 containers per min. The CDFI Canister Feeder accurately dispenses single or multiple canister drops with a simple selector switch. It features a simple set-up, and accepts canisters from all major manufacturers. Among the CDFI Canister Feeder's key attributes are its ease of use and versatility: the unit does not require bottle-change parts and, with the appropriate tooling, can accommodate various-sized canisters from 1, 2 and 3 g. Changeover takes less than 5 min, and the machine can be supplied with a 5-gal canister reservoir or 10-gal hopper with elevator. — *Omega Design Corp., Exton, Pa.*
www.omegadesign.com

Blister machine handles a wide range of forming materials

The EAGLE-Omni blister machine (photo) is suitable for packaging development, materials testing and production. The unit performs forming, sealing and punching operations at sequential stations. The cost-effective, deep-draw EAGLE-Omni is capable of everything from manual prototyping to fully automated operation. The machine handles a wide range of forming materials, including PVC, PVDC, ACLAR, PP, PET and ALU — and all typical lidding substrates including ALU, paper, PVC, PET and laminates. The EAGLE-Omni can produce up to 20 blisters per min, and is suitable for packaging solids, powders, liquids or devices.— *Maruho Hatsujyo Innovations (MHI), Quincy, Mass.*
www.mhi-innovations.com

New motion-control portfolio delivers flexibility and more

The PACMotion servo motion-control portfolio (photo) offers an integrated automation solution for high-performance industrial applications. The portfolio includes a new motion controller that connects directly into the PACSystems RX3i programmable logic-controller backplane for high-speed, high-precision performance with synchronized motion for up to 40 coordinated axes, enabling end users to scale up their motion systems without sacrificing performance. The complete PACMotion portfolio includes a motion controller, servo motors, servo drives and motion-configuration software for applications in packaging, printing, material handling, semiconductors, food and beverage, and general manufacturing. The patented technology enables precise, jerk-free positioning, preventing material slippage and production losses and improving machine efficiency. — *Emerson, St. Louis, Mo.*
www.emerson.com

New double rotary tablet-press technology to be launched

Available this fall, the XT 600 HD Double Rotary Tablet Press (photo) combines key facets of the company's proven technology in a cost-effective platform for technical and chemical products with large formats, deeper filling depths and higher compression forces. It offers high-speed production capabilities for both single-layer and bi-layer tablets. Among other applications, the XT 600 HD has proven extremely effective in the production of salt tablets, catalysts, detergents and fertilizer tablets. The high-capacity feeding system and robust compression column design deliver unparalleled tablet quality and production output. Both the pre-compression and main-compression columns can deliver 120 kN of compression force — sufficient even for the most difficult-to-compress products. — *Korsch America Inc., South Easton, Mass.*
www.korsch.com

Augmented reality enters this packaging platform

This company is extending its platform capabilities to support augmented reality (AR) on its Rockwell Automation-enabled packaging solutions. The company has entered beta-phase testing and is targeting commercial availability for its AR option this year (photo). AR represents a leap forward for staff knowledge transfer — employing digital visual overlays through a combination of both handheld and hands-free devices. It supersedes traditional approaches to operator training and maintenance of industrial assets. AR presents a powerful solution for producers seeking to alleviate the well-known upskilling issues associated with high labor turnover, productivity and error-proofing. — *Harpak-ULMA, Taunton, Mass.*
www.harpak-ulma.com

Omega Design

Maruho Hatsujyo Innovations (MHI)

Emerson

Korsch America

Harpak-ULMA

Fortress Technology

Mactac

Verti-Lift

Best Process Solutions

Southworth Products

A new series of smart check weighers

This company recently unveiled its expansion into check weighing, with the launch of its inaugural smart weigher series, Raptor. Raptor check weighers include an intelligent conveyor-removal system and intuitive digital process-monitoring technology to advance inspection efficiency, target operational inefficiencies and slash product giveaway. The Raptor launch range comprises three systems: a single frame standalone checkweigher, a combination metal detector and checkweigher (photo), and XL caseweighing system for ingredient and big bag applications. All three address North America's calls for robust, accurate, hygienic and compact food-weight control systems incorporating the very latest digital smart-processing technology. — *Fortress Technology Ltd., Toronto, Ont., Canada*
www.fortresstechnology.com

Heat-resistant labels for high-temperature applications

Withstanding temperatures as high as 572°F, these new heat-resistant labels are part of this company's Lintec Durable Goods and Industrial Labeling product line. They are designed for barcode applications, such as circuitboards (photo), electronics, automotive components and appliances. The new labelstocks were designed to stand up to extreme heat, solder, fluxes, solvents and chemicals. They have a heat-resistant adhesive that is paired with a heat-resistant top-coat enabling them to maintain whiteness, barcode legibility, and adhesive performance when exposed to temperatures as high as 572°F for up to 10 min. The heat-resistant topcoat is also resistant to abrasion and ribbon smudging. Labels can be digital or thermal-transfer printed. — *Mactac, Stow, Ohio*
www.mactac.com

A new packing station with integral conveyors

These new packing stations (photo) combine a full-length work area adjacent to a full-length integral conveyor for speeding the container, product or component to its next destination. Built on the company's tandem scissor-lift platform, these extra-long packing stations can be raised or lowered to meet the application needs of manufacturing, processing, distribution operations and more. The units are available with lift capacities to 6,000 lb, and platform sizes up to 48 in. × 220 in. They can also be fabricated as custom units when larger platform size or capacity is necessary. — *Verti-Lift, Inc., Louisville, Ky.*
www.verti-lift.com

This bulk-bag filler has a pallet dispenser

The bulk bag filler with wooden pallet dispenser (photo) automatically places an empty pallet under a bulk bag before filling. Between 14 and 16 pallets can be loaded for staging into the pallet dispenser. Controls automatically remove the bottom pallet from the stack and place it below the bulk bag before filling occurs. Once the bulk bag is filled, a power roller discharges the filled bulk bag and pallet onto an accumulation conveyor (not shown) for transport to warehouse. The wooden pallet dispenser reduces the need for an operator to place an empty pallet under each bag, thus reducing the operators needed to maintain a high bag-filling rate. — *Best Process Solutions, Inc., Brunswick, Ohio*
www.bpsvibes.com

This tilter loads conveyors and sorters quickly

A new Gaylord (box) tilter is a fast, efficient way to get parcels and other items from Gaylords and other large containers onto conveyors and automated sorting systems. The Model GTU-500 (photo) tilts loads up to 110 deg to provide controlled emptying of container contents. It features a unique pan-style platform that sits essentially flush with the floor when lowered, allowing Gaylords to be placed and retrieved by a hand pallet truck — no forklift necessary. A steel retention bar prevents Gaylords from falling, even when the unit is tilted to the full 110 deg. Unloading container contents with a tilt device like the GTU-500 makes work faster, safer and easier, which translates into higher productivity and reduced workers strain and injury, says the company. — *Southworth Products Corp., Portland, Maine*
www.southworthproducts.com

Modified atmosphere technology for FIBCs

This supplier of flexible intermediate bulk containers (FIBCs) packaging has developed a special technology for FIBC packaging known as Modified Atmosphere Packaging (M-A-P). The M-A-P technology (photo) can be applied to adjust oxygen levels within the packaging to the desired range. This makes it possible to control and monitor the decay and oxidation process in a precise way in order to improve the supply chain management and shelf life. Combined with the company's non-invasive Sensor Spot technology, using a fluorescence signal to measure oxygen level inside the packaging, no openings whatsoever have to be made to the packaging material, preserving the quality inside and protecting it from contamination risks from the outside. These oxygen measurements can be repeated as often as needed without destroying the packaging in any way. Also, all bulk packaging is produced in Class 10,000–100,000 cleanrooms, further minimizing risks of contamination and pests. All types of products, such as nuts, foods, ingredients, pharmaceuticals, hemp, chemicals and especially harvested products can benefit from this technology. — *Masterpack Group B.V., Enschede, the Netherlands*
www.masterpackgroup.com

A modular labeling machine boasts long service life

The modular Innoket Neo Flex machine (photo) features quick-change modules for highly flexible labeling applications. Furthermore, thanks to the low maintenance effort and very long service life users benefit from low operating costs, says the manufacturer. Thanks to the Innoket Neo's flexible design, the individual modules on this highly customizable labeler can be freely combined. Depending on the machine size and requirements, the Flex series can be equipped with two to four modules. The machine labels both plastic and glass containers and cans in all standard sizes. The output totals up to 74,000 containers per hour. — *KHS Group, Dortmund, Germany*
www.khs.com

Gerald Ondrey

Masterpack Group

KHS Group

New Products

Emerson Industrial Automation

CV Technology

Dustcontrol UK

A redundant control system for emergency shutdown valves

The ASCO 141 Series advanced redundant control system (ARCS; photo) provides a redundant solution for a variety of emergency-shutdown valve applications. The system includes various redundant solenoid configurations to enhance the reliability of the process and meet specific safety or reliability requirements in automation processes. The single-inlet/single-outlet design provides a streamlined installation process compared to traditional bypass systems, while almost eliminating potential failure points, according to the manufacturer. The ASCO 141 Series ARCS is designed for use as a component in safety instrumented systems, and it functions as a redundant pneumatics-tripping device to control the pilot-air signal to a process-valve actuator. The ARCS features either two or four electrically actuated solenoid valves, visual indicators and a manually controlled bypass or isolation valve. The unique control functionality allows for maintenance of the solenoid valves without having to shut down the process valve. Furthermore, the use of the maintenance bypass or isolation valve is not required for functional testing of the ARCS unit — a downtime-reducing feature not possible with common bypass functions. — *Emerson Industrial Automation, St. Louis, Mo.*

www.emerson.com

A new explosion-isolation device with patented features

The Interceptor-QV explosion-isolation device (photo) uses a patented system where a differential pressure switch continuously monitors the pressure drop across the mesh cartridge, alerting operators if buildup of dust occurs on the mesh. The core feature of the Interceptor-QV is the stainless-steel mesh cartridge, which is based on this company's flameless quench tubes. If a deflagration propagates through the clean return line, it will make contact with the mesh cartridge, which will immediately and passively remove energy from the flame front of the deflagration as it passes through the torturous path of the mesh. This forces the flame to transfer its energy to the high surface area of the mesh, thereby quenching the deflagration and not allowing any flame to pass beyond the Interceptor-QV. Another patented feature of the Interceptor-QV is an integrated thermocouple (TC), which, when exposed to the intense heat of a deflagration, will indicate, via relay, that the system has been involved in an event. — *CV Technology, Jupiter, Fla.*

www.cvtechnology.com

An upgraded range of mobile dust-control products

The DC Tromb line of dust extractors (photo) features several recently updated models. The recently remodelled versions of the Tromb range meet modern safety requirements while offering ergonomic and modular functions. One of the major updates is that the new DC TrombTwin model is separable, meaning the dust extractor and pre-separator are easily detached and re-assembled from each other to make transport simple. Other updates to the range include a simpler filter-change system and a motor package that is easier to remove. In addition, improved motors and a sturdier chassis have significantly expanded the capabilities of the Tromb product range, says the manufacturer. — *Dustcontrol UK Ltd., Milton Keynes, U.K.*

www.dustcontroluk.co.uk

New clamp provides secure, easy-access sealing

The new C-30 C-clamp (photo, p. 21) permanently mounts on machinery while retracting easily without tools for quick access to the interior of a variety of machinery, such as dryers, mixers, conveyors, tanks and reactors. The new clamp delivers up to 1,700 lb of clamping force to establish a tight seal on machine panels, doors, housings, screen decks and other equipment, even when joining different materials and multiple thicknesses. For quick release and machine access, the C-30 clamp features a proprietary, stainless-steel yoke and roll-pin as-

sembly that allows opening with one hand and no tools without detaching the clamp from the machinery. When cleaning, inspection or maintenance is complete, the clamp may be returned to the closed position at the desired tension in seconds to resume safe machine operation. The C-30 clamp eliminates the need for steel bolts, rivets, welds and other fastening methods that inhibit access. Complete cleaning and product changeovers move smoothly, without concern for confined space entry. The clamp comes in cast aluminum and stainless-steel construction, or in FDA-approved 303 stainless steel to meet USDA regulations and 3-A standards for the food and dairy industries. — *The Witte Co., Washington, N.J.*
www.witte.com

Chemical-resistant membranes for electrolysis

Forblue S-Series ion-exchange membranes (photo) are designed for electrolysis and electrodialysis applications that require robust chemical-resistance performance. Because they are made from fluorinated resins, all S-Series wet and dry grades ensure chemical resistance and mechanical strength, while providing outstanding current-carrying capability. Forblue S-Series grades are cation-exchange membranes with a sulfonic acid group. They provide high cation-selective permeability for electrolysis or electrodialysis and offer ion-exchange capacities from 1.0 to 1.25 meq/g. The high ion-exchange capacity enables very low resistance with high ion selectivity. S-Series wet and dry membranes are available in a wide array of thicknesses. If processing requirements demand reinforcement, S-Series membranes are available with special polytetrafluoroethylene (PTFE) fabric. — *AGC Chemicals Americas Inc., Exton, Pa.*
www.agcchem.com

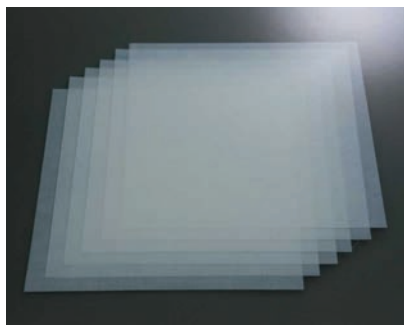
These centrifugal pumps handle very high temperatures

The System One Series of high-temperature centrifugal pumps (photo) utilizes flanges, elastomers and a unique centerline mount to support high operating temperatures. These design features allow System One high-temperature pumps to safely and reliably transfer critical and valuable fluids in a wide variety of high-temperature applications, including thermal oils, petrochemicals, heat-transfer fluids, plastics and more. The System One Series is pre-configured to meet temperature requirements of up to 450°F (232°C) with the 450°F Line, 650°F (343°C) with the 650°F Line, and even 750°F (398°C) with additional configurations and factory consultation. These pumps have been specifically designed to increase the temperature limits for this company's Frame A and Frame M centrifugal pumps while offering the same mechanical performance. System One Series high-temperature pumps offer capacities up to 1,400 gal/mim (5,299 L/min), and incorporate high-temperature bushings, fasteners and paint. — *Blackmer, part of PSG, a Dover Company, Grand Rapids, Mich.*
www.blackmer.com

Flexible, cut-resistant gloves for manufacturing and construction

SmartCut BKCR2403 cut-resistant gloves (photo) are designed for jobs that not only need cut and abrasion resistance, but still require a focus on long-wearing grip, dexterity and flexibility. This light-duty, cut-resistant glove offers ANSI Cut Resistance Level 2 protection balanced with extreme dexterity for tasks calling for very fine motor skills and tactile sensitivity. Its composite yarn includes a blend of high-strength filament fibers for cut resistance, upwound with nylon and spandex to enable high levels of dexterity. The 18-gauge high-performance polyethylene and glass-fiber shell is lightweight and provides the ANSI cut level 2 protection. A black polyurethane palm coating delivers reliable abrasion protection and enhanced grip. SmartCut BKCR2403 gloves are versatile enough to be used for light-duty job functions in diverse industries, such as construction, glass handling, HVAC, manufacturing and metal fabrication — *Brass Knuckle Safety Products, Alpharetta, Ga.*
www.brassknuckleprotection.com

The Witte Co.


AGC Chemicals Americas


Blackmer


Brass Knuckle Safety Products

SensoTech

Hans Turck

Krohne

ECOM Instruments

This immersion sensor is now certified for hazardous areas

The LiquiSonic ultrasonic sensor is suitable for determining concentration and density of process liquids, as well as for monitoring crystallization, polymerization and phase separation. The Korea Testing Laboratory (KTL) has now confirmed and certified the suitability of the LiquiSonic 40-40 immersion sensor (photo) for use in explosion-proof environments. During certification, all components of the sensor are tested with regard to the ignition protection type of flameproof enclosure and assessed accordingly. The certificate attests to the high quality standards this company sets for its products. The robust sensor design is also maintenance-free and resistant to external influences, such as vibrations. Now, users in Korea can efficiently increase the process capability, safety and overall efficiency of their processes in explosion-proof areas. — *SensoTech, Inc., Jersey City, N.J.*
www.sensotech.com

Compact temperature sensors with plug-and-play options

This company is expanding its range of fluid sensors with IO-Link-capable sensors for flexible and reliable process temperature measurement. Both compact devices are equipped with an integrated temperature probe (TS700), as well as processing and display units (TS720) for connecting resistance thermometers or thermocouples (photo). The TS+ sensors meet the growing demand for straightforward commissioning and high plant availability. This is supported by the robust stainless-steel housing with touch operation instead of mechanical operating elements, which are ideally suited for use in harsh industrial environments thanks to IP67 and IP69K protection. Besides process values, the IO-Link interface provides the user with a large volume of condition-monitoring data for smart IIoT applications. To simplify commissioning, the TS+ devices also feature automatic detection of the output type (PNP/NPN or current/voltage), as is already offered by the PS+ and FS+ pressure and flow sensors. Compact TS700 devices operate in a measuring range from –50 to 150°C. Depending on the temperature probe connected, type TS720 processing and display units can even cover temperature ranges between –200 and 1,800°C. — *Hans Turck GmbH & Co. KG, Mülheim an der Ruhr, Germany*
www.turck.com

A tool for device commissioning and advanced certification

The new Opticheck DTM (photo) was recently introduced for device commissioning and in-situ verification. This expands the company's myDevice smart tools product line. Opticheck DTM is a device-commissioning product that services a diverse array of operating systems. It offers advanced verification capabilities without any process interruption, making it an efficient choice for regulated products. With powerful diagnostic functions and an extensive self-test option that provides information about the device status, the Opticheck DTM is suitable for operators seeking information on device health. The system is available in both control-room and onsite settings, proving its adaptability to different environments. — *Krohne, Inc., Beverly, Mass.*
www.us.krohne.com

An intrinsically safe Bluetooth remote speaker microphone

Reliable communication is particularly important for lone workers in hazardous areas. To secure workers' safety and working conditions, this company offers a wireless Bluetooth (BT) remote-speaker microphone (photo) with an operating time up to 78 h. The RSM-Ex 01 BT Z0 comes with an IP65/67 rating and a built-in noise-reduction function. It produces clear, high-volume audio up to 103 dB. The remote-speaker microphone is tough, compact and ergonomic to wear on the body. It is intuitive and easy to use, even when wearing gloves. The built-in BT Interface allows a connection to industrial BT devices, such as radios, tablets and smartphones. The speaker microphone provides additional buttons, such as a red SOS emergency button so workers can call for help quickly and easily, connecting to the company's headquarters or directly to an emergency-operations center nearby. — *ECOM Instruments GmbH, a Pepperl+Fuchs brand, Assamstadt, Germany*
www.ecom-ex.com

Use these electromagnetic flowmeters for batching

New MIM electromagnetic flowmeters (photo) provide accurate readings in a space-saving design. With extensive options for onsite programming, they are suitable for a wide variety of applications, particularly in batching operations, such as matching media during coating of tablets or during coolant supply. Their electromagnetic nature means there are no moving parts, making these devices effective in measuring the flow of conductive media, such as water, pulps, pastes or emulsions. Configurable optical buttons can be used to display parameters, including flowrates or temperatures. A changing color system in the display also provides warnings for limit violations. Since the MIM is produced in a remote version, the flowmeter can also be used with media temperatures from –40 up to 284°F. In addition to the temperature measurement function, the MIM can be used for very small nominal pipe sizes and covers an even larger measuring range, depending on the nominal pipe size. — *Kobold Instruments, Inc., Pittsburgh, Pa.*

www.koboldusa.com

Kobold Instruments

New protective clothing handles high-pressure water

The company is augmenting its Livmoa range of single-use protective clothing to include to new Livmoa 4000 products (photo) for high-pressure water applications, such as those in waste-disposal sites or any type of heavy-duty cleaning task. Furthermore, in subsequent months, new Livmoa CL sterilized clothing for cleanrooms will also be available to the market. Livmoa 4000 is breathable, and employs a proprietary SMS (spunbond-meltblown-spunbond) nonwoven fabric. The clothing thus protects wearers from dust and can also withstand a water pressure of 1,000 mmH_2O column. The meltblown layer keeps dust and water out while also delivering air permeability. Livmoa 4000 complies with the JIS Type 5 and 6 standards for chemical protective clothing. — *Toray Industries, Inc., Tokyo, Japan*

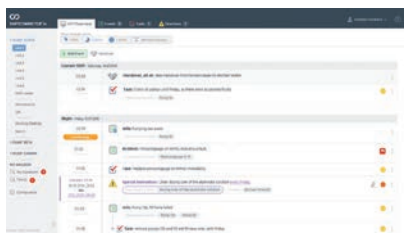
www.toray.co.jp

Toray Industries

This platform for shift handover now includes health data

This company's Shiftconnector digital manufacturing software (photo) for the processing industries can now be integrated with the Cleared4 employee-health monitoring platform. This partnership aims to promote healthy, safe and reliable production at manufacturing plants. This combined software platform is said to be the first shift-to-shift handover software in the industry to directly address the multitude of health and safety issues brought on by the COVID-19 pandemic. The solution simultaneously solves digital communications and collaboration challenges during shift-to-shift handovers, including reporting and contract tracing, management of process upsets and compliance-related routine activities. The integration of Cleared4 with Shiftconnector provides a health-management dashboard, including text messaging, health-centric technologies and on-site kiosks to obtain valuable health clearance and optimize safety as employees enter a facility to start their shift. Additionally, the platform gives access to COVID-19 test results for staff and integrates Influenza and COVID-19 vaccination status. — *Eschbach North America Inc., Boston, Mass.*

www.eschbach.com



Eschbach North America

This corrosion inhibitor tackles high-moisture conditions

VpCI-396 is a very hard but flexible corrosion-inhibiting coating that cures in high-humidity conditions. VpCI-396 is a solvent-based moisture-cure urethane that can be used as a direct-to-metal (DTM) primer, and in some cases a topcoat. It provides protection in harsh, outdoor, unsheltered applications and cures best when applied under relative humidity of 20–80% with temperatures ranging from 32–120°F (0–50°C). This makes it a good option for structural steel and tanks in a chemical- or water-vapor-rich industrial environment. VpCI-396 can be used over this company's CorrVerter Rust Converter Primer on previously rusted surfaces. — *Cortec Corp., St. Paul, Minn.*

www.cortecvci.com ■

Mary Page Bailey and Gerald Ondrey

Temperature Influences on Rupture Disk Burst Pressure

Department Editor: Scott Jenkins

Rupture disks are non-reclosing pressure-relief devices that protect vessels, such as reactors, from damaging over-pressurization (or vacuum) conditions. Temperature can affect rupture-disk burst pressures in ways that users should understand before ordering them (Figure 1). This one-page reference provides an overview of the issues that temperature effects can cause for rupture disk selection and performance.

Rupture disks are available in various designs, sizes, shapes and set pressures. Reverse-buckling rupture disk designs are generally the first choice for overpressure protection because they have greater longevity, accuracy and reliability over time. Reverse-buckling rupture disks are also designed for non-fragmentation, which is recommended when using rupture disks to isolate downstream pressure-relief valves from a process. When used in this way, rupture disks typically allow for higher operating pressures while ensuring inlet-side leak tightness, lower valve maintenance expenses, and frequently the use of lower-cost valve trim.

Coincident temperature

Prior to ordering a rupture disk, design engineers must specify several characteristics of the disk to satisfy the overpressure protection requirement. One of these is the specified temperature of the disk, often called the "coincident temperature." This term is defined as the stable temperature of the rupture disk when it is required to activate (burst).

Since a rupture disk is typically manufactured from metal foils, the environment on either side of the disk determines the coincident temperature. While a precise temperature can be difficult to determine, the relief-system design engineer should consider the conditions on either side of the disk and specify the disk at a temperature as close to the coincident temperature as possible.

For rupture disks to meet the requirements of consensus standards, burst-pressure accuracy is validated through destructive testing of samples from a batch (lot) of disks that are manufactured from the same material at the same time and at the temperature specified for that particular rupture disk description. If the stable temperature of a disk at the time of rupture is not properly selected, the disk is incapable of bursting at its marked burst pressure.

Specification errors

Designers often erroneously specify the disk temperature at the "flowing temperature" of the discharged media. That value is rarely correct and is usually the result of "relief-valve mentality" — the rupture disk doesn't "care" what flows through it … only the environment and conditions that exist when it bursts. It is likewise inappropriate to specify the rupture disk at the process operating temperature or ambient (72°F or 22°C) temperature.

If the disk is specified at a temperature higher than its true coincident temperature at the time of activation, that rupture disk should be expected to activate at a pressure higher than its marked burst pressure, possibly creating an unsafe condition. If the disk is specified at a temperature lower than its true coincident temperature, it will typically activate below its marked burst pressure, resulting in unnecessary lost production time. For example, if a disk is installed 20 feet downstream of the process, past two elbows, the intervening pipe acts as a heat sink, and the coincident disk temperature is significantly below the process temperature.

On the other hand, a rupture disk specified at a dramatically lower temperature than the true coincident temperature, or if the process encounters considerably higher temperature than the specified temperature of the rupture disk, the high-temperature environment can actually "stress relieve" the disk, resulting in a permanent shift in the temperature/burst pressure curve. Occasionally, that condition can result in disks activating critically higher than the marked burst pressure of the lot (batch). Accordingly, in addition to the specified temperature of the rupture disk, the maximum operating temperature of the process should be communicated to the manufacturer to ensure thermal stabilization of the rupture disk up to and including the maximum exposure temperature while in service.

FIGURE 1. The environment on either side of the rupture disk determines the coincident temperature

The deviation from the marked burst pressure of a disk resulting from improperly specified coincident temperature is a function of the type (model) of the disk, as well as the material(s) of construction.

Since almost all rupture disk designs have more than one manufacturing variable, the temperature influences on burst pressure alone cannot be accurately predicted. Additionally, each "heat" of material has slightly differing mechanical properties, which significantly limit the reliability of standardized temperature correction data for any given rupture disk type and material.

Disks may be tested at two or more different temperatures (upon request) and documentation accompanying the disks may show the burst pressures at temperatures other than those defined as the specified temperature. However, for rupture disks to comply with the relevant ASME code, the specified coincident temperature of the rupture disk and corresponding pressure can only be marked at one temperature. Any additional temperature testing and corresponding burst pressures determined and validated is not specifiable and will not appear on the rupture disk tag as a marked burst pressure. ■

Editor's note: the material contained in this column was contributed by Steven S. Palmer, BS&B Safety Systems, LLC (Tulsa, Okla.; www.bsbsystems.com).

Butyl Acrylate from Acrylic Acid and Butanol

By Intratec Solutions

Butyl acrylate, the butyl ester of acrylic acid, is among the most industrially important acrylates (along with methyl acrylate and ethyl acrylate). The major use of butyl acrylate is in the production of acrylic polymers, and for making copolymers with polyethylene. It is also used in the formulation of paints, sealants, cleaning products and adhesives, as well as in amphoteric surfactants, aqueous resins, antioxidant agents, elastomers and dispersions for textiles and papers.

Butyl acrylate can be produced from several reactions involving acetylene, 1-butyl alcohol, carbon monoxide, nickel carbonyl, and hydrochloric acid among other chemicals. On an industrial scale, butyl acrylate is produced from ester-grade acrylic acid and butanol, typically in plants that are integrated with acrylic acid facilities.

The process

The present analysis discusses an industrial process for butyl acrylate production. The process comprises two major sections: (1) esterification; and (2) purification (Figure 1).

Esterification. Acrylic acid, a small excess of butanol and *p*-toluene sulfonic acid catalyst are fed to the reaction system. The esterification reactor is connected to a distillation system for continuous removal of water from the reactor medium. This improves the reaction kinetics and shifts the reaction toward ester formation. Organic compounds recovered in the bottoms are recycled to the esterification reactor, while water is used as a solvent for catalyst extraction.

Purification. Recovered water is fed to a catalyst extraction column to separate catalyst from previously cooled reaction product withdrawn from the second reactor. The catalyst stream is recycled to the esterification reactor. The crude product is fed to a wash column, where residues of acrylic acid and catalyst are neutralized with a caustic solution and separated from the crude product as the column bottom stream. The top stream is distilled to recover butanol, which is sent to the dehydration distillation column upstream. In the last purification step, a column separates residual organic heavy wastes from the crude butyl acrylate stream, yielding high-purity butyl acrylate as column overhead. The organic heavy material is directed to the decomposer reactor, where extra butyl acrylate is recovered by the catalytic reaction of heavy byproducts.

Production pathways

Butyl acrylate is primarily made from acrylic acid and butanol, in a variety of manufacturing routes that differ according to the sources of raw materials. In this context, typical butyl acrylate production routes are based on acrylic acid manufacturing, mostly via propylene oxidation, and, to a lesser extent, oxidative carbonylation of ethylene (Figure 2).

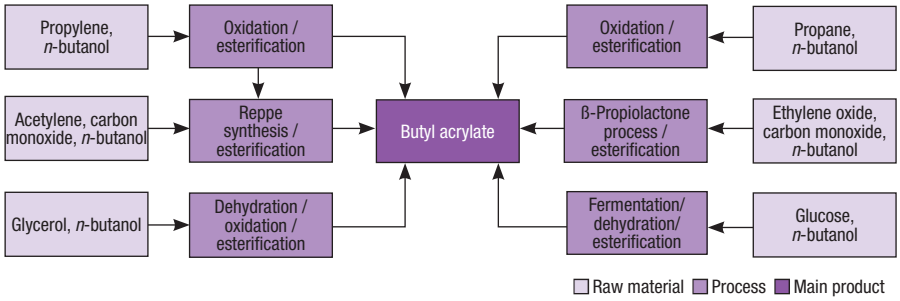


FIGURE 2. Several different production pathways exist for butyl acrylate

Economic performance

The total operating cost (raw materials, utilities, fixed costs and depreciation costs) estimated to produce butyl acrylate was about $1,400 per ton of butyl acrylate in the first quarter of 2017. The analysis was based on a plant constructed in the U.S. with capacity to produce 150,000 metric ton per year of butyl acrylate.

This column is based on "Butyl Acrylate Production from Acrylic Acid and Butanol – Cost Analysis," a report published by Intratec. It can be found at: www.intratec.us/analysis/butyl-acrylate-production-cost. ■

Edited by Scott Jenkins

Editor's note: The content for this column is supplied by Intratec Solutions LLC (Houston; www.intratec.us) and edited by *Chemical Engineering*. The analyses and models presented are prepared on the basis of publicly available and non-confidential information. The content represents the opinions of Intratec only. More information about the methodology for preparing analysis can be found, along with terms of use, at www.intratec.us/che.

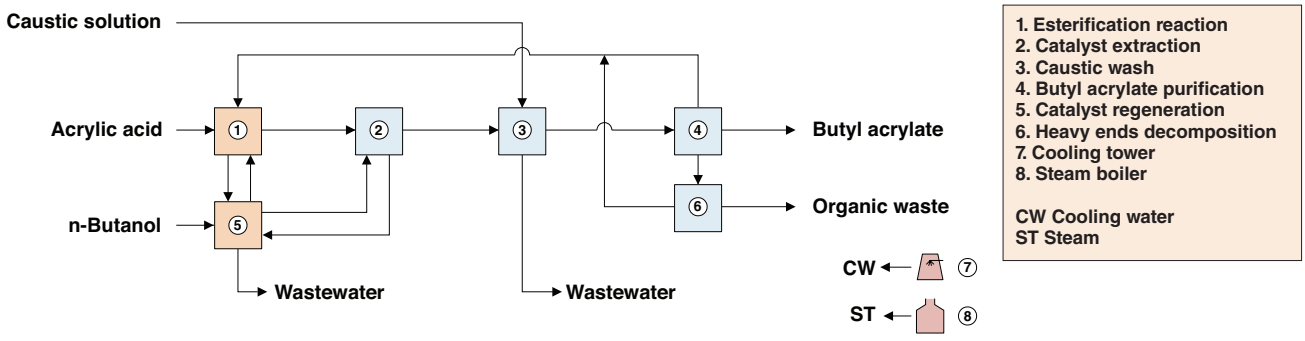


FIGURE 1. The diagram represents a process for the production of butyl acrylate via conventional esterification

Unlock the Energy Potential of Your Plant

By exploring strategies for process integration, such as waste-heat recovery and combined heat and power generation, plants can significantly improve their energy efficiency and reduce utility costs

Yee Heng Ang and Dominic C. Y. Foo
University of Nottingham Malaysia

IN BRIEF

In a chemical processing plant, utility costs typically account for about 10 to 20% of the total product cost [*1*]. Advancements in systematic techniques for better utilization of energy, such as through process integration, had received recognition following the fuel crisis in the 1970s [*2*]. Apart from economic reasons, improving energy management also brings environmental advantages, such as reductions in greenhouse-gas emissions.

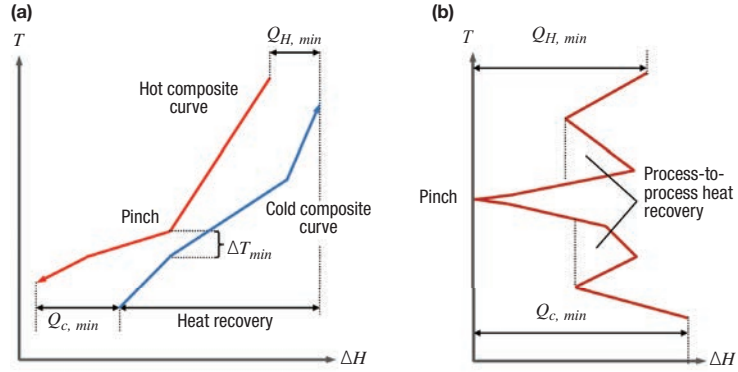


FIGURE 1. Two of the most important tools for design optimization of energy-intensive processes are the heat-recovery pinch diagram (a); and the grand composite curve (b)

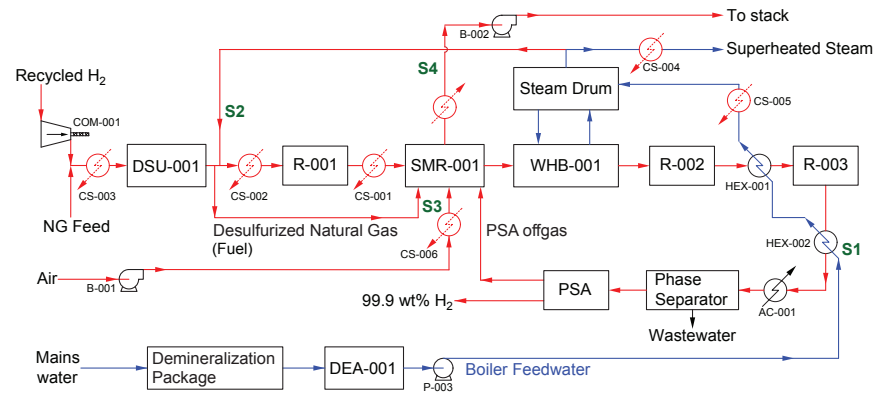
Process integration can be defined as a holistic approach to design and operation that emphasizes the unity of the process [*3*, *4*]. Since the 1970s, various process-integration tools have been developed for heat-exchanger network synthesis, as well as for the optimization of various energy-intensive processes, and are well documented in literature [*5*, *6*]. Two such important tools showing the relationship between heat flow and temperature are the heat-recovery pinch diagram and the grand composite curve (GCC), both shown in Figure 1.

Note that in many cases, however, processes have been designed without much concern for energy utilization. Hence, the opportunities for energy optimization have never been fully explored. Through detailed inspection, many energy-saving opportunities can be easily identified, especially with regard to utilities. These activities lead to a more energy-efficient plant, with lower energy consumption and operating costs.

This article outlines the steps to evaluate an energy-intensive process to improve its energy utilization. To achieve this, example stream data were used for process integration. This example demonstrates how improvements in flowsheet design can help save energy. For instance, instead of supplying energy for process heating utilities, the process improvements identified ways that excess energy could be used for reactor integration, as well as options for combined heat and power (CHP) generation for the process.

TABLE 1. HEAT INTEGRATION DATA FOR THE BASE CASE

Stream	Description	Stream	T_{supply} (°C)	T_{target} (°C)	ΔH (MW)	CP (MW/°C)
1	Demin. water	Cold	99.00	245.00	18.91	0.130
2	SMR-001 air	Cold	10.00	150.00	2.08	0.015
3	DSU-001 feed	Cold	40.00	360.00	1.99	0.006
4	R-001 feed	Cold	296.34	550.00	3.63	0.014
5	SMR-001 feed	Cold	550.00	800.00	4.15	0.017
6	R-002 feed	Hot	800.00	350.00	–7.81	0.017
7	R-003 feed	Hot	350.00	215.00	–2.26	0.017
8	PSA feed	Hot	215.00	40.00	–2.86	0.016
9	SMR-001 fluegas	Hot	1,056.00	550.00	–13.00	0.026



Legend					
AC	Air Cooled HEX	DEA-001	Deaerator	R-001	Pre-reformer
B	Blower	DSU-001	Desulfurizer	R-002	High-temperature WGS
COM	Compressor	HEX	Heat Exchanger	R-003	Low-temperature WGS
CS	Convective Section	P-003	Pump	SMR-001	Steam Methane Reformer
		PSA	Pressure Swing Adsorption	WHB-001	Waste Heat Boiler

FIGURE 2. The process-integration strategies outlined here relate to a steam-methane reforming (SMR) plant. Note that streams S1, S2, S3 and S4 are placed where the process-integration strategies are employed

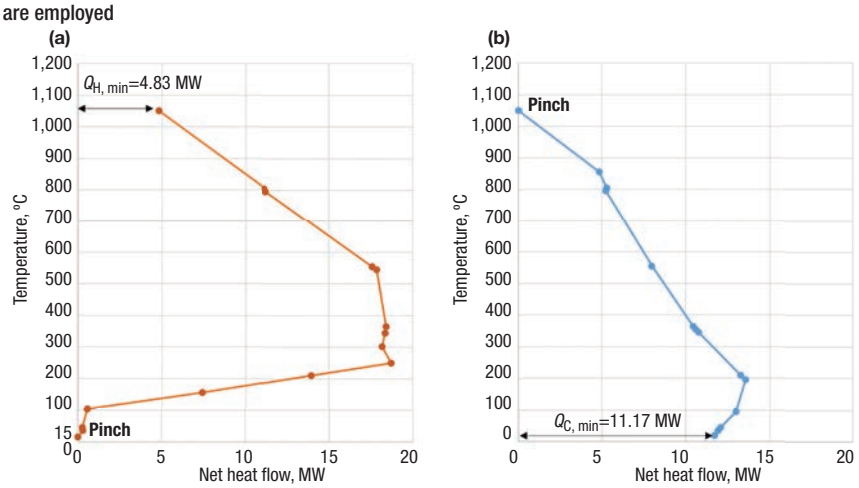


FIGURE 3. The GCCs displaying the minimum utility targets are shown for (a) the base case; and (b) the flowsheet with subsequent process-modification strategies, which reveals excess energy availability

Example — H_2 production

The analysis outlined in this article relates to a hydrogen-production plant situated in a petroleum-refinery complex in Northwest England. However, the general principles will be applicable to many types of heat-exchanger networks.

At this site, hydrogen (H_2) is produced for use in the refinery's hydrotreating and hydrocracking units, and also for export to a nearby fertilizer manufacturing facility. The steam methane reforming (SMR) process is employed for the production of hydrogen. Figure 2 shows the process flow diagram (PFD) of the SMR plant.

A fresh feedstream of natural gas (NG) is mixed with a small portion of recycled hydrogen product before the mixture is pre-treated within the desulfurizer (DSU-001) and pre-reformer (R-001) units. In the latter unit, hydrogen sulfide, mercaptans and heavier hydrocarbons are removed. The desulfurized NG then enters the tubular furnace reactor (SMR-001), which is operated at 1,056°C. The NG serves two purposes in the SMR-001 unit: as supplementary fuel; and as a reactant for the steam-reforming process, along with steam. As a result, synthesis gas (syngas) is produced from the reaction between water and methane. The heat from the fluegas is recovered in the convective section of SMR-001 (down to 550°C) before stack discharge.

Syngas effluent from SMR-001 is next cooled in a waste-heat boiler (WHB-001) before passing to a high-temperature water-gas shift (WGS) reactor (R-002) and then a low-temperature WGS reactor (R-003). In both reactors, carbon monoxide and water react to form carbon dioxide and hydrogen. The hydrogen-rich stream then undergoes air-cooling (in AC-001) in order to condense any water vapor, while its gas mixture passes through a pressure-swing adsorption (PSA) unit for the separation of hydrogen. The offgas from the PSA is sent to SMR-001 as fuel.

Figure 3(a) shows the GCC of the base case, which indicates that the minimum hot utility target ($Q_{H, min}$) of the process is identified as 4.83 MW, for a minimum approach temperature (ΔT) of 10°C, without any cold utility requirement (data for the heat integration study is given in Table 1). Note that this situation is termed as a "threshold problem" in process integration literature [6]. Figure 3(b) shows the GCC for the process,

TABLE 2. HEAT INTEGRATION DATA FOR THE REVISED CASE

Stream	Description	Stream	T_{supply} (°C)	T_{target} (°C)	ΔH (MW)	CP (MW/°C)
1	Demin. water	Cold	30.00	90.00	0.79	0.013
2	SMR-001 air	Cold	15.00	850.00	13.12	0.016
3	Natural gas feed	Cold	40.00	360.00	1.96	0.006
4	Produced hydrogen	Cold	40.00	360.00	0.02	0.000
5	R-001 feed	Cold	360.00	550.00	1.37	0.007
6	R-001 steam	Cold	350.00	550.00	0.13	0.001
7	SMR-001 feed	Cold	550.00	800.00	2.34	0.009
8	SMR-001 steam	Cold	350.00	800.00	2.01	0.004
9	R-002 feed	Hot	800.00	350.00	–7.32	0.016
10	R-003 feed	Hot	350.00	215.00	–2.13	0.016
11	PSA feed	Hot	215.00	40.00	–2.86	0.016
12	SMR-001 fluegas	Hot	1,056.00	200.00	–21.15	0.025

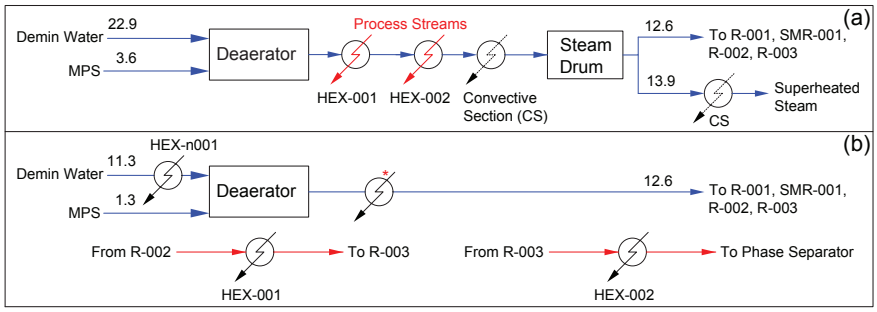


FIGURE 4. The Strategy 1 process modification involves utility distribution for the process; (a) displays the original utility distribution; and (b) displays the revised utility distribution (flowrate in ton/h). Note that the unit marked with the * symbol represents the four HEX units shown in Figure 8

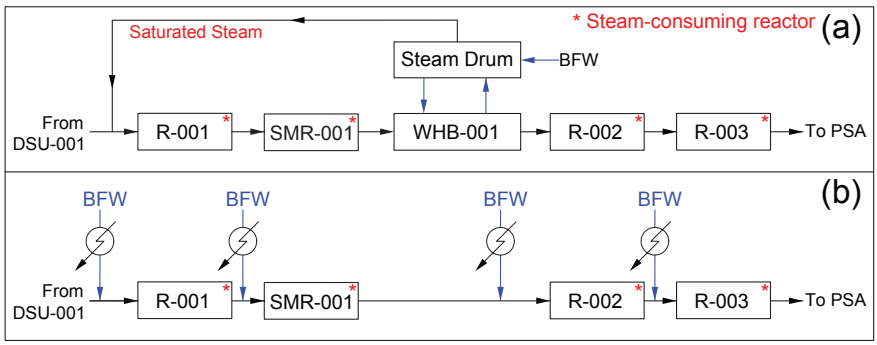


FIGURE 5. The configuration in (a) shows steam distribution in the base case, while (b) shows the revised setup described in Strategy 2, which resulted in a reduction in reactor heating requirements

following the modifications that are outlined in the following sections. These modifications reveal excess energy availability.

Energy reduction strategies

In general, the energy efficiency of a process can be improved by the following techniques [7]:

1. Reducing waste and losses
2. Optimizing process operation
3. Heat-recovery improvement
4. Identifying process changes
5. Optimizing energy-supply systems

These techniques are the underlying concepts used in developing the process-improvement strategies outlined in this article.

According to Ref. 6, heat recovery can be further increased by exploiting the process conditions that possess flexibility and freedom to be changed (within process limits). The SMR design evaluated in this article consists of several units that can be explored for improving energy efficiency, such as furnaces, boilers, reactors, stacks and so on. The following section describes four such strategies for enhancing heat recovery, leading to overall lower energy consumption. Stream data for these revised heat-integration steps are given in Table 2.

Strategy 1: Utilities. In the base case, medium-pressure steam (MPS) is fed to the deaerator (DEA) in order to remove the oxygen content of the demineralized (demin.) water before it is heated in heat exchangers HEX-001 and HEX-002, as well as the furnace convective section, in order to produce steam. However, an excess amount of steam is fed to the DEA, so it can be sold as superheated steam after further heating. Upon inspection, only 48% (12.6 ton/h) of the 26.5 ton/h of generated steam is actually required as a reactant in the plant.

Next, the boiler feedwater (BFW) that was originally used as the cooling medium in HEX-001 and HEX-002 is removed. Doing this leads to a lower demin. water flowrate, as it is no longer constrained by the heat-transfer requirement of the heat exchangers. The heated demin. water stream from the DEA is treated as individual cold streams for steam generation in the reactors (see Strategy 2 below for details). An extra heat exchanger (HEX-n001) is used for heating the demin. water from 30 to 90°C before it enters the DEA. Following the data-extraction heuristics in Ref. 6, HEX-001 and HEX-002 are extracted as hot streams, while HEX-n001 is extracted as a cold stream in pinch analysis. As a result, an extra 4.98 MW of excess energy is available for heat integration. These process modifications are shown in Figure 4.

Strategy 2: Reactor steam supply. In the base-case process, the saturated steam from the steam drum (shown in red in Figure 5) is mixed with the feed of the pre-reformer. Four reactions consume steam (R-001, SMR-001, R-002 and R-003). The saturated steam is supplied to the pre-reformer in excess such that no additional makeup is required in subsequent reactors. Consequently, a large proportion of steam is present in each of the reactor streams. The excess steam is heated and

TABLE 3. RESULTS FROM THE FOUR STRATEGIES

Strategy	Parameter	Before	After	Remarks
1	BFW flowrate (feed to DEA)	26.5 ton/h	12.6 ton/h	Additional 4.98 MW of excess energy is available for heat integration
2	Reactor feeds heating utility	17.86 MW	16.16 MW	Reduction of 1.7 MW in the heating requirements
3	Heat flow supplied by NG	22.63 MW	3.81 MW	Reduction of 1,440 kg/h of NG
4	Fluegas heat flow	70.6 MW	78.9 MW	An extra 8.3 MW is available for heat integration

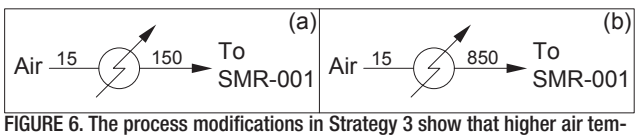


FIGURE 6. The process modifications in Strategy 3 show that higher air temperature of 850°C (b) enables better heat integration over the base case (a)

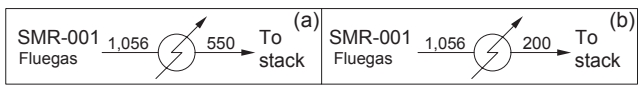


FIGURE 7. With Strategy 4, shown in (b), fluegas exhaust temperature (°C) can be reduced, leading to energy savings over the base case (a)

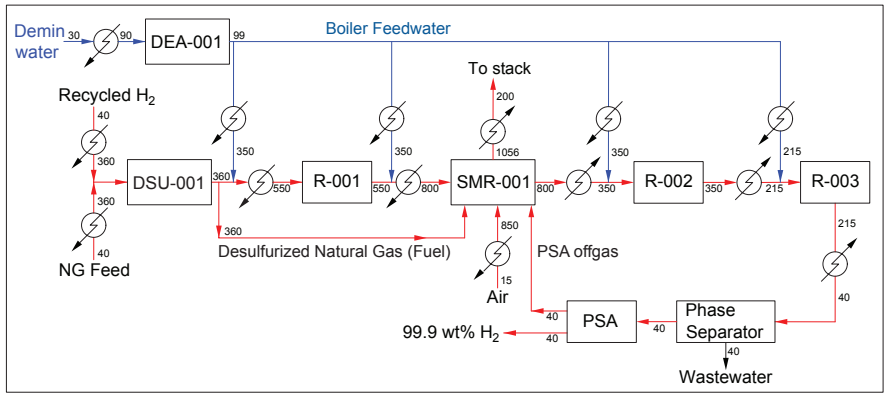


FIGURE 8. The revised PFD of the SMR unit shows the process modifications described in Strategies 1 through 4. Note that values indicate stream temperatures in °C; and pumps, and compressors and blowers are ignored in this PFD

cooled along with the process fluid. This incurs a large energy demand on heating utilities, which can be avoided. In the revised design, steam is supplied separately to each reactor as feedstock with the distributed steam-supply system. This results in a reduction of 1.7 MW in the heating requirements for the reactor feeds.

Strategy 3: Natural-gas fuel consumption. The offgas from the PSA system is fed as fuel into SMR-001, with a portion of desulfurized NG used to satisfy the fuel deficit. The furnace operates at 1,056°C, while the combustion air enters the burners at 150°C. The design calls for extra NG to heat the fuel-air mixture in SMR-001.

To reduce NG consumption, the air stream is heated to 850°C to allow for better heat integration with other hot process streams. In other words, better heat recovery will take place to raise the temperature of this air stream. Doing so leads to less fuel being needed in the SMR-001 furnace — a decrease from 1,732 down to 292 kg/h. An additional benefit is the reduction of the stack loss, which leads to improved thermal efficiency in the furnace [6]. Figure 6 shows the combustion air temperatures in both the base case, and following modified heating to improve heat integration.

Strategy 4: Fluegas exhaust temperature. In the base case, the hot fluegas from the SMR reactor is discharged to the stack after it is cooled to 550°C. Since this is a hot stream in pinch analysis, its discharge temperature should be reduced in order to maximize its heat-recovery potential. In other words, additional heat will be made available to heat up other cold streams in the process. Note also that the furnace efficiency can be improved when the stack exhaust temperature is lowered [6]. However, the temperature should be kept higher than the acid dewpoint, where condensation takes place. For this process, the fluegas is to be cooled to 200°C in order to maximize its energy recovery. This leads to an additional 8.3 MW of energy being recovered from the SMR reactor's hot fluegas. Figure 7 shows the implementation of this process modification.

Evaluate the results

The revised PFD (after all process modifications) is shown in Figure 8, and a summary of all four strategies' results is given in Table 3. Note that this PFD is meant for use in energy optimization with pinch analysis. Performing pinch analysis following the standard procedure resulted in the GCC shown in Figure 3(b). Instead of needing heating utility input of 4.83 MW as in the base case in Figure 3(a), the process now can generate an excess energy of 11.70 MW, indicated by the cold utility target ($Q_{c,\,min}$), as seen in Figure 3(b). In other words, the process is transformed from being energy-intensive into one with excess energy availability. It is worth noting that the removal of 4.83 MW of hot utility consumption results in an avoidance of 7.86 million ton/yr of CO_2 emissions (assuming natural gas is used). Figure 3(b) also shows that the process has a very high pinch temperature of 1,051°C. This further shows that the excess heat of the process is rejected from high-temperature sources. These high-grade waste-heat sources have the potential to be better utilized in the plant, which is discussed in the following section.

TABLE 4. UNIT COSTS OF UTILITIES

Utility	Unit cost
VHPS	£13/ton ($17.72/ton)
HPS	£11/ton ($15/ton)
MPS	£9/ton ($12.27/ton)
Cooling water	£0.015/ton ($0.020/ton)
NG fuel	£450/ton ($613/ton)
Electricity	£40/MWh ($54.52/MWh)

Reactor integration and CHP

The high-grade excess heat revealed by the revised process layout has various options for usage in the process. These include the heating of endothermic reactors, steam generation or power generation through a combined heat and power (CHP) scheme. Such measures not only save energy and reduce plant operating costs, but also enhance a company's overall sustainability efforts. For the hydrogen-production unit described in this article, Figure 9 shows the various ways of making use of high-grade waste heat, as follows:

- Heat integration for the endothermic reactor (R-001)
- Steam generation (to be used as a reactant in R-001, R-002, R-003 and DEA)
- Steam generation to be used for

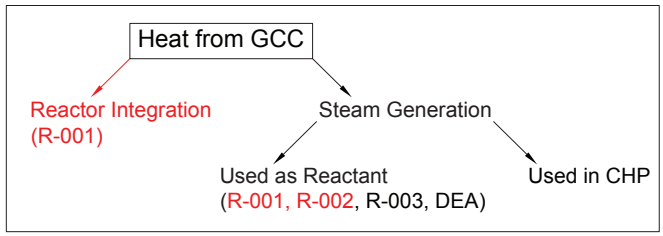


FIGURE 9. The energy utilization tree for both scenarios shows methods for waste-heat use (Scenario 1 is shown in black only; Scenario 2 is shown in black and red)

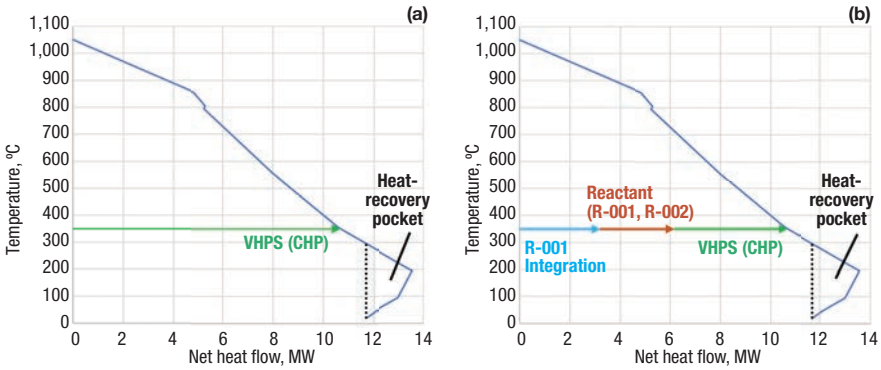


FIGURE 10. The GCCs for Scenario 1 (a) and Scenario 2 (b) show the design optimization that can be achieved through these process modifications

power generation in the CHP scheme

Two scenarios are analyzed, with cost data given in Table 4. Note that the utility cost for the revised PFD in Figure 8 was determined to be £7,678,088/yr ($10,465,672/yr), inclusive of power (1.75 MW) and energy utilities. The latter includes cooling water and NG fuel needed for VHPS generation as reactant. In Scenario 1, all waste heat is used to generate 2.99 kg/s of very high-pressure steam (VHPS) to be used for power generation in a CHP scheme. The rationale behind Scenario 1 is to maximize the cogeneration potential before other design choices. The VHPS needed as reactant in R-001, R-002 and SMR-001 was purchased externally. The high-pressure steam (HPS, 0.50 kg/s) and MPS (0.38 kg/s) produced from the CHP scheme are used as reactant in R-003 and DEA, respectively. This scenario has a cogeneration potential of 0.48 MW, calculated using the model given in Ref. 8. The total project cost was determined to be £6,930,609/yr ($9,446,815/yr), which takes into account the capital costs for a new turbine and heat-recovery steam generator, as well as cost savings from power and revenue resulting from MPS (excess generation from CHP) that is sold to nearby plants. The total savings for this scenario is determined to be £747,479/yr ($1,018,856/yr), a 9.74% reduction compared to the total cost of the revised design.

For Scenario 2, the generated VHPS is also utilized for the integration of the endothermic reactor (R-001), as well as for VHPS used as reactant in reactors R-001 (0.31 kg/s) and R-002 (0.66 kg/s). This results in a much smaller cogeneration potential, of 0.164 MW (calculated using the model in Ref. 8), but also much lower NG fuel expenditure for the VHPS generation for the reactors. Note that the HPS and MPS produced from the CHP scheme are used as reactant in R-003 and DEA, as in Scenario 1. For this case, much higher total savings are obtained — £1,416,981/yr ($1,931,426/yr) — almost double that in Scenario 1. Hence, a significantly lower project cost of £6,261,107/yr ($8,534,246/yr) is achieved. Scenario 2 clearly demonstrates better economic performance among the two scenarios analyzed. The economic parameters of the scenarios are summarized in Table 5.

It is clear from these analyses that energy usage for a process plant can be further optimized in order to explore its additional benefits. Figure 10 displays the respective GCCs for Scenarios 1 and 2, illustrating the heat-flow effects of the various process modifications. In most cases, the excess heat may be used for power or steam generation, for instance through a CHP scheme. Process modifications may be carried out to improve energy efficiency of the plant and to lower its utility consumptions. As shown in this article, the application of a CHP system in the hydrogen-production plant brings an additional cost savings of £1,416,981 (over $1.9 million). ■

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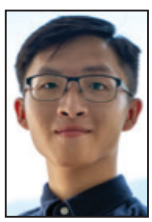
TABLE 5. COMPARISON AMONG BASE-CASE DESIGN WITH CHP SCENARIOS

Scenario	*Base case*	*1*	*2*
Cogeneration potential (MW)	—	0.480	0.164
Project costs	£7,678,088/yr ($10,465,672/yr)	£6,930,609/yr ($9,446,815/yr)	£6,261,107/yr ($8,534,246/yr)
Total savings	—	£747,479/yr ($1,018,856/yr)	£1,416,981/yr ($1,931,426/yr)

References

1. Peters, M. S., Timmerhaus, K. D. and West, R. E., "Plant Design and Economics for Chemical Engineers," 5th ed., McGraw-Hill, New York, 2004.
2. Rossiter, A. P., "Energy Management and Efficiency for the Process Industries," Wiley-AIChE, 2015.
3. El-Halwagi, M. M., "Sustainable Design Through Process Integration," Butterworth-Heinemann. Kidlington, Oxford, U.K., 2012.
4. El-Halwagi, M. M. and Foo, D. C. Y., "Kirk-Othmer Encyclopedia of Chemical Technology," John Wiley & Sons. Hoboken, N.J., 2014.
5. Linnhoff, B. and Boland, D., "A user guide on process integration for the efficient use of energy," The Institution of Chemical Engineers (IChemE), Rugby, Warks, U.K., 1982.
6. Smith, R., "Chemical Process Design and Integration," 2nd ed., John Wiley & Sons, Ltd., Chichester, West Sussex, U.K., 2017.
7. Zhu, F., "Energy and Process Optimization for the Process Industries," Wiley-AIChE. Hoboken, N.J,, 2013.
8. Ng, R. T. L., others, Targeting for cogeneration potential and steam allocation for steam distribution network, *Applied Thermal Engineering*, Vol. 113, pp. 1,610–1,621, 2017.

Authors



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Protecting Steam Systems from Corrosion

Steam and condensate-return systems can be susceptible to unique forms of corrosion. This overview explains how to prevent or minimize such issues

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ChemTreat, Inc.

Steam is utilized for process heating and other applications at thousands of industrial plants in the chemical process industries (CPI). Often, a significant portion of the steam condensate is recovered and returned to the boilers. Depending on the plant processes the steam serves, the condensate may contain any number of impurities that range from acidic compounds to organics to mineral salts. These impurities can cause corrosion and failure of condensate return piping and equipment, and they can potentially induce serious steam-generator corrosion and fouling. This article provides an overview of several critical issues in this regard and outlines techniques for chemically treating the steam/condensate and polishing the condensate return to reduce corrosion and scaling potential.

Potential boiler problems

The steam generator itself may be the source of a common condensate impurity: carbon dioxide. High-pressure utility boilers require high-purity makeup (contaminants not exceeding low parts-per-billion concentrations) as a result of the high temperatures and pressures in these units. However, the much lower heat fluxes and pressures in many industrial units allow less stringent makeup. Table 1 outlines some general guidelines, extracted from a well-known American Society of Mechanical Engineers (ASME) booklet [*1*] regarding impurity limits in low- to medium-pressure industrial water-tube boilers. The booklet contains additional details on these guidelines.

A popular makeup treatment for many boiler units, and especially those operating under 300 psi pressure, is basic sodium zeolite softening to exchange calcium and magnesium, the hardness ions, for sodium. This minimizes the potential for common scale deposit formation, with calcium carbonate ($CaCO_3$) being the most prevalent.

$$Ca^{2+} + 2HCO_3^- + \text{heat} \rightarrow CaCO_3 + CO_2 + H_2O \quad (1)$$

However, sodium softening does not remove other impurities, including bicarbonate alkalinity (HCO_3^-). On reaching the boiler, this constituent is in large measure converted to carbon dioxide via the following reactions:

$$2HCO_3^- + \text{heat} \rightarrow CO_3^{2-} + CO_2 + H_2O \quad (2)$$

$$CO_3^{2-} + \text{heat} \rightarrow CO_2 + OH^- \quad (3)$$

The total conversion of CO_2 from the combined reactions may reach 90%. CO_2 flashes off with the steam, and, when it re-dissolves in the condensate, can increase the acidity of the liquid.

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + CO_3^{2-} \quad (4)$$

Although the pH generated by this reaction has a relatively mild lower limit, the acidity is more than enough to cause significant carbon steel corrosion. For example, 3 parts per million (ppm) of CO_2 in pure steam condensate will lower the pH to 5.26. If dissolved oxygen is present in the system, corrosion can be greatly magnified.

FIGURE 1. Shown here is a skid-mounted reverse osmosis (RO) unit

Several methods are available to counteract the influence of CO_2 carryover with steam. One choice is to upgrade the makeup treatment system to capture or remove alkalinity. A scheme utilized in years past was split-stream dealkalization, with a sodium softener and strong acid cation exchanger placed in parallel, followed by a downstream forced-draft or vacuum decarbonator. Both sets of ion-exchange resins remove hardness, but the acid generated by the cation exchanger converts alkalinity to CO_2, which is removed in the decarbonator. The process does not remove other impurities, including chloride, sulfate or silica, which then concentrate in the boiler and must be controlled by blowdown.

Another alkalinity removal method is dealkalization in the chloride mode. This ion-exchange process utilizes an anion exchanger directly after the softener. The anion unit removes total alkalinity and sulfate ions. If caustic is added, natural CO_2 is removed along with some silica. However, for every part of alkalinity removed, one part of chloride is added. Nearly complete alkalinity removal can be

attained, but this may require an increase in boiler blowdown because of the added chlorides.

A more modern approach comes from the maturation of water-treatment membrane technologies. Reverse osmosis (RO) is a core component of many makeup water treatment systems (Figure 1), and even a single-pass RO can remove over 99% of the impurities from the makeup.

Such technology can often be the best choice for a new plant, where the steam-generation chemical-treatment program is selected for the higher-purity makeup. However, careful thought and planning is needed if such a change is made at an existing facility. The switchover from softened or dealkalized makeup water would most likely require other changes to the chemical-treatment program, especially the internal boiler water treatment.

For those plants where sodium softening remains the preferred choice, chemical control of CO_2 is possible. Such control ties in with an important aspect of feedwater chemistry outlined in Table 1: maintaining the feedwater pH in a mildly alkaline range. In fact, operating results over the years indicate that feedwater pH should typically be maintained closer to the upper limit of the 8.3–10.0 range shown in the table to minimize feedwater piping iron corrosion. This is particularly true in the power industry, where flow-accelerated corrosion (FAC) has been a serious problem [*2*].

The common feedwater pH-conditioning chemical for power plants is ammonia, which raises the pH via the following reaction:

$$NH_3 + H_2O \leftrightarrow NH_4^+ + OH^- \qquad (5)$$

This is an equilibrium reaction, and, thus, the alkalinity increase is limited, which usually minimizes excessive steel corrosion in the event of a chemical feed upset. (Copper alloy corrosion is a completely different story.) But ammonia is very volatile, and the compound significantly partitions with steam in low-pressure boilers. For industrial units, neutralizing amines are a common alternative for feedwater pH conditioning (Table 2). These are small-chain organic molecules with an ammonia group attached to, or embedded within, the compound.

Two important properties of these compounds are the distribution ratio and basicity. Some of the amines have a higher basicity than ammonia and can raise the pH to higher levels if necessary. Another important property for systems with condensate return is the distribution ratio, that is, the amount of amine that carries over with steam versus the amount that remains in the water. The ratios vary with boiler temperature and pressure, but some products tend to remain in the boiler water while others significantly partition with the steam. Careful selection of a blended product can provide comprehensive pH conditioning to the boilers and

TABLE 1. GUIDELINES FOR IMPURITY LIMITS IN LOW-PRESSURE INDUSTRIAL BOILERS

Drum operating pressure (psig)	0–300	301–450	451–600
Feedwater			
Dissolved oxygen (mg/L) measured before oxygen scavenger injection	<0.007	<0.007	<0.007
Total iron (mg/L as Fe)	≤0.1	≤0.05	≤0.03
Total copper (mg/L as Cu)	≤0.05	≤0.025	≤0.02
Total hardness (mg/L)	≤0.3	≤0.3	≤0.2
pH @ 25°C		8.3–10.0	8.3–10.0
Non-volatile TOC (mg/L)	<0.1	<0.1	<0.05
Oily matter (mg/L)	<0.1	<0.1	<0.05
Boiler water			
Silica (as SiO_2)	≤150	≤90	≤40
Total alkalinity (mg/L as $CaCO_3$)	<700	<600	<500
Free hydroxide alkalinity (mg/L)	NS*	NS*	NS*
Specific conductance (µmhos/cm @ 25°C)	5,400–1,100	4,600–900	3,800–800
Total dissolved solids in steam			
TDS maximum (mg/L)	1.0–0.2	1.0–0.2	1.0–0.2

* NS = Not specified

condensate return system.

A critical aspect in developing chemical-treatment programs for condensate system protection is an understanding of all system metallurgy. Typically, the piping is carbon steel, in which the most corrosive agents are dissolved oxygen and acids. For copper-alloy heat-exchanger-tube materials, combining ammonia with dissolved oxygen can be quite harmful. Stainless steels perform best in oxygenated environments, but some mineral salt anions, most notably chloride, can cause localized pitting and stress corrosion cracking (SCC), the latter mechanism being greatly influenced by temperature. Sulfide is deleterious to many metals. So, no evaluation of a chemical-treatment program is valid without knowledge of all materials within the condensate return system and the conditions to which the metals are subjected.

Before moving to the next section, two additional points should be noted. First, when representatives of the authors' employer audit a new system, they frequently see boilers with overheating or corrosion (or both) problems. Further research often reveals previous upsets or failures of the sodium softening system. The resultant hardness in-leakage to the boilers generates the reaction shown in Equation (1), among others. As these incidents and the case study in the next section suggest, the focus at industrial plants is often concentrated on process chemistry and engineering, and the water/steam systems take a backseat in terms of attention and funding, at least until a major problem arises.

Second, much work continues in the development of film-forming products, either amine-based or other compounds with alternative active groups, for steam-system metals protection. Much of the effort so far has been concentrated in the power industry. Film-forming chemistry is not new, but improved products are now available to make this technology more attractive. However, questions remain about the efficiency of these products and whether they can provide complete protection to all metal surfaces. Space limitations prevent a discussion of this chemistry now, but we hope to provide details in a future article. In the meantime, please contact the authors for additional information.

Condensate return system

This section begins with a case study. A number of years ago, one of the authors and a colleague were asked to visit an organic chemicals plant with four 550-psig

FIGURE 2. The pipe shown here is nearly blocked with iron oxide corrosion products

package boilers with superheaters. Much of the steam utilized for energy in the plant heat exchangers was returned as condensate to the boilers. Each of the boiler superheaters would fail every 1.5–2 years on average because of deposition and subsequent overheating within the tubes. An inspection of an extracted superheater tube bundle in a laydown area revealed deposits of approximately 1/8–1/4 in. in depth. Additional inspection revealed foam issuing from the saturated steam sample line of each boiler. Among the items evident from water/steam analyses previously performed by an outside vendor were total organic carbon (TOC) levels of up to 200 ppm in the condensate return. Contrast that with the <0.05 feedwater TOC recommendation in Table 1. No processes or equipment were in place to remove these organics upstream of the boilers. Based on that evidence alone, it was easily understandable why foam was issuing from the steam sample lines, and why the superheaters rapidly accumulated deposits and failed from overheating.

With the wide variety of intermedi-

TABLE 2. COMMON NEUTRALIZING AMINES

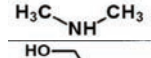
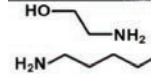
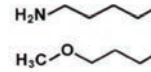
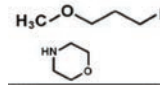
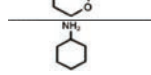
Amine	Chemical Formula	Molecular Weight (g/mol)	Structure
Dimethylamine	C_2H_7N	45.08	
Ethanolamine	C_2H_7NO	61.08	
5-Aminopentanol	$C_5H_{13}NO$	103.16	
3-Methoxypropylamine	$C_4H_{11}NO$	89.14	
Morpholine	C_4H_9NO	87.1	
Cyclohexylamine	$C_6H_{11}NH_2$	99.2	

FIGURE 3. Shown here is an iron-digestion unit / spectrophotometer for grab samples

ate and final products generated by industrial plants, the possibilities for contaminant leakage into condensate return are enormous. Besides the examples noted above, other impurities may include strongly acidic or basic compounds, mineral salts, complex organics, and many additional contaminants, including oxygen from air in-leakage, which can cause intense carbon-steel corrosion and corrosion-product transport (Figure 2).

As we have noted, products that might not cause corrosion or scaling in the condensate return system can still travel to the boilers to induce major problems.

So, what are some useful methods to protect return condensate and minimize impurity ingress to boilers? One method is to establish and maintain heat exchanger integrity so impurities do not enter the condensate. A common argument is that systems are so complex or have so many components that keeping track of all the heat exchangers is a nearly impossible task. However, we believe such an effort should be part of the plant's overall safety program. Too many examples are available where an old, corroded component failed and triggered a major accident.

One possibility for steam-generator protection is to equip the condensate return system with a dump line so an excursion in some instrument reading, say, specific conductivity, will open a valve and allow the condensate to be drained rather than returned to the steam generators. Some plants use TOC analyzers to monitor return condensate.

TABLE 3. CARBON STEEL CORROSION

Millipore	Condition	Potential Corrosion Rate
<25 ppb	Minute corrosion	<0.5 mpy
<50 ppb	Slight	<2.0 mpy
<100 ppb	Good	<5.0 mpy
<300 ppb	Fair	>5 to <10 mpy
>300 ppb	Poor–Heavy	10+ mpy

If neutralizing amines are utilized for pH adjustment, the contributing TOC from the amine is taken into consideration, and a target TOC is selected for dumping. Dumping can involve a large loss of water and may require special makeup water system design to handle periodic high makeup requirements. An alternative idea, albeit one that requires additional funding and staffing, is to place a condensate polisher on the return line to the boilers. The choice of equipment and polishing process will depend on the impurities to be removed and mechanical conditions such as flowrate, temperature, and pressure; but a number of options are available, including the following:

- Ion-exchange resins, with some flexibility of selection for particular contaminants
- Particulate-matter removal by fabric or mechanical filters

Ion-exchange resins can be specifically designed to remove a variety of dissolved ions, ranging from primary cations and anions to other trace constituents. A difficulty with resins is that, depending on the resin type, they may be more or less limited by temperature. Some anion resins begin to break down at temperatures not much higher than 100°F, while others may be stable at substantially higher temperatures.

Direct filtration with a fabric medium is a common technique, particularly if system corrosion generates a significant amount of iron oxide or other metal particulate matter. A prime example comes from the power industry, where air-cooled condensers (ACC) have become somewhat popular as an alternative to cooling towers as a method to conserve water. ACC units require a huge amount of carbon-steel piping to effectively cool turbine exhaust steam, and even with the best chemical treatment programs, the process still introduces a large amount of iron oxide particulates to the condensate. These particles must be removed before entering the steam generator, as they can deposit on boiler tubes to reduce heat transfer and potentially establish locations for under-deposit corrosion.

Monitoring condensate

The recommended online water/steam chemistry analyses for high-pressure steam generators is described in Ref. 3. Prompt detection of chemistry upsets can save a plant huge sums by preventing steam generator corrosion and failure. The data are also important for helping plant personnel maintain day-to-day chemistry within proper ranges.

The same logic applies to monitoring condensate return chemistry. Valuable analyses, depending on process conditions, may include the following:

- pH
- Specific and cation conductivity
- TOC
- Sodium (a common and easily measurable impurity in cooling water)
- Iron or Millipore testing (or both)

Improved grab-sampling techniques for iron monitoring can (Figure 3), with proper sample treatment, measure total iron concentrations down to 1 part per billion (ppb). This method can provide nearly realtime corrosion rate data, although on a "snapshot" basis.

Millipore testing (passing a fixed volume of condensate through a 0.45-micron Millipore filter pad and comparing the coloration to standard charts) and trending of the return condensate will show whether the corrosion products are reddish (hematite) or darker gray-black (magnetite), and if condensate conditions are changing. Table 3 is a rough guide to carbon-steel corrosion in the condensate system.

The importance of iron monitoring has become very well recognized in the power industry, but it can be equally valuable at many other facilities as well. ■

Edited by Gerald Ondrey

Disclaimer

This discussion represents good engineering practice developed over many years. However, it is the responsibility of plant owners, operators, and technical personnel to set up reliable chemical feed, control and monitoring systems based on consultations with industry experts. Many additional details go into the design and subsequent operation of these technologies than can be outlined in this article. Each system is different, and we encourage you to contact experts for a consultation.

References

1. "Consensus on Operating Practices for the Control of Feedwater and Boiler Water Chemistry in Modern Industrial Boilers," The American Society of Mechanical Engineers, New York, NY, 1994.
2. Buecker, B., Shulder, S., and A. Sieben, Fossil Power Plant Cycle Chemistry; pre-conference seminar to the 39th Annual Electric Utility Chemistry Workshop, Champaign, Illinois, June 4, 2019.
3. Buecker, Brad, Monitoring of Water and Steam Chemistry for Steam Generation, *Chem. Eng.*, September 2019, pp. 33–42.

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Area Electrical Classification in Research Applications: Is It the Only Mitigative Choice?

Area electrical classification is a powerful tool for process safety. It is not, however, the only viable approach to a safe process

Richard Palluzi
Richard P Palluzi LLC

Electrically classifying an area is a long-standing safety measure in the petrochemical and related industries. It is also an area that is not taught in schools and most practitioners pick up as part of their on-the-job training. As a result, it is also an area prone to many misconceptions. While its application is always challenging, its application in a research environment is even more difficult. The need for constant process and equipment changes, the desire to modify and rearrange operations and equipment, the need to strike out in totally different areas all make flexibility a major requirement (Figure 1). And an electrically classified area is relatively restrictive in what can and can't be done. So, unfailingly, research organizations look for alternative mitigative measures.

Requirements

Do research operations involving flammable and combustible materials always require the organization to electrically classify the area?

NFPA [National Fire Protection Assn.] 70 The National Electric Code in 500.5(A) requires that "*Locations shall be classified depending on the properties of the flammable gas, flammable liquid–produced vapor, combustible liquid–produced vapors, combustible dusts, or fibers/flyings that could be present, and the likelihood that a flammable or combustible concentration or quantity is present.*"

The U.S. Occupational Safety and Health Admin. (OSHA) in 1910.307(a)(1) uses similar language. OSHA 1910.119 considers electrical classification as a vital piece of process safety information that should be readily available but does not make it a mandatory requirement.

Many other NFPA codes require some specific areas to be electrically classified. NFPA 30 The Flammable and Combustible Liquids Code in Table 7.3.3 gives some specific guidance as to how some areas, like tank farms and vents, should be classified. However, 7.3.1 states that electrical equipment shall not "*constitute a source of ignition for any ignitible vapor that might be present under normal operation or because of a spill. Compliance with 7.3.2 through 7.3.7.1 shall be deemed as meeting the requirements of this section.*" The word "deemed" is important here because it implies that if you follow the code guidance, you can assume you comply with ensuring that electrical equipment will not "*constitute a source of ignition for any ignitible vapor that might be present under normal operation or because of a spill*" without much further analysis.

But what if you are willing to do that further hazard analysis and risk assessment? Can you use other mitigative measures? The answer is a resounding maybe.

NFPA 497 Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas states three conditions are necessary for ignition of a flammable or combustible material in 4.3:

(1) A combustible material must be present.
(2) It must be mixed with air in the proportions required to produce an ignitible mixture.
(3) There must be a release of sufficient energy to ignite the mixture.

API 500 Recommended Practice for Classification of Locations for Electrical Installations at Petroleum

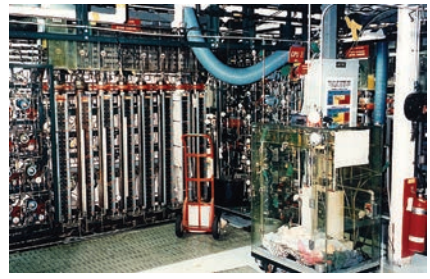

FIGURE 1. An electrically classified area, such as Class 1, Div. 2 for this pilot plant, can be relatively restrictive, especially when there are frequent process and equipment changes

Facilities Classified as Class I, Division 1 and Division 2 expands on these conditions in 4.1:

a) A flammable gas or vapor must be present. In classifying a particular location, the likelihood of the presence of a flammable gas or vapor is a significant factor in determining the division classification. The decision is based principally on whether the flammable mixture may be present (1) under normal conditions, or (2) only under abnormal conditions (including equipment breakdown).

b) The gas or vapor must be mixed with air or oxygen in the proportions and quantities required to produce a flammable or ignitable mixture. This condition is important in determining the limit or extent of the classified location. The quantity of the substance that might be liberated, its physical characteristics, the operating pressure, and the natural tendency of gases and vapors to disperse in the atmosphere should be considered.

c) The mixture must be ignited. When classifying locations, the potential source of ignition is understood to be an electrical installation or device operating at energy levels or at temperatures sufficient to cause ignition.

Neither API 500 and NFPA 497 are suggesting that area electrical classification is the only way to pre-

vent a fire or explosion. Rather they say that if you follow their guidelines then, historically, you are usually safe from fires and explosions. They are recommending one way to stay safe, not the only way. If you can provide adequate mitigative measures to prevent one or more of the above three conditions from being present, then area electrical classification is not the only possible approach.

NFPA 497 is clear in 5.2 saying "*The decision to classify an area as hazardous is based on the possibility that an ignitible mixture could occur.*" API 500 in section 6.1 echoes this guidance. "*The decision to classify a location is based on the probability that flammable gases or vapors may be present. … It is noted that the occurrence of flammable material liberation from some of the above apparatus is so infrequent and at such a small rate, that it is not necessary to consider it as a source or to classify adequately ventilated nonenclosed areas containing such apparatus.*" If you provide mitigative measures to reduce the possibility that an ignitable mixture could occur to less than a credible possibility, then the area does not need to be electrically classified.

Realistic mitigation measures

The key to this is what mitigative measures can realistically be applied.

Limit the amounts. The first approach might be to limit the amount of flammable and combustible materials to a *de minimis* amount. While 44 mL of flammable liquid is enough to catch fire, the realistic amount of damage one shot glass of liquid can produce has not suggested that we electrically classify bars. Yet a bar involves open transfers, open containers, frangible containers, and a very high probability for spills and human error. Despite this, we know — from experience — that bars do not catch fire due to flammable and combustible liquid handling with any degree of frequency. While no code addresses how much flammable or combustible material is enough to be of concern, consider that pint, quart, and even gallon containers of flammable or combustible materials are sold, handled, and used in homes, businesses and stores with incredible frequency with relatively low consequences. Hence, I suggest that quantities of 1 gallon (~4 L) or less are probably small enough to be considered *de minimis*. Note, however, that when one talks about the quantity of flammable or combustible material present, one must include all the flammable or combustible material in the given area; not just an individual container. So, while I would not worry about a single 1-gal container of hexane in a laboratory, I would be more concerned if it were one of a dozen.

This limiting approach may be feasible for some research applications but, in most cases — particularly those handling flammable gases or utilities — it may not be very practical nor useful.

Ventilation. A second approach might be to provide so much ventilation that the flammable or combustible material is captured at the source and the extent of any ignitable area is negligible (Figure 2). Note that I carefully avoided the term "adequate ventilation", which is used extensively in all the codes.

Adequate ventilation is defined in NFPA 30 section 17.1.1 as "*a rate sufficient to maintain the concentration of vapors within the area at or below 25 percent of the lower flammable limit (LFL).*" NFPA 497 in 3.3.1 defines it as:

A ventilation rate that affords six air changes per hour, 1 cfm per square foot of floor area (0.3 $m^3/min/m^2$), or other similar criterion that prevents the accumulation of significant quantities of vapor-air concentrations from exceeding 25 percent of the lower flammable limit (LFL).

API 500 in section 3.1.38 uses similar language:

Ventilation (natural or artificial) that is sufficient to prevent the accumulation of vapor-air or gas-air mixtures in concentrations above 25% of their lower flammable (explosive) limit, LFL (LEL).

API 500 expands upon this definition in section 6.3.2 where it gives practical guidance in this area. However, API 500 limits the use of ventilation, allowing ventilation to lower the electrical classification of a location from Division 1 to Division 2 but not be used to lower the electrical classification of a location from classified to unclassified.

FIGURE 2. Ventilation is an important mitigation measure. This pilot plant is skid mounted, and can be easily moved into a hood

Some organizations feel this guidance prohibits ventilation as a mitigative measure. I disagree. API 500 tacitly assumes that there is always a credible possibility of the presence of a flammable or combustible material in ignitable quantities in most areas of a petrochemical facility, a not unreasonable assumption. Hence using ventilation as a mitigative measure is not realistic since, in most cases, the adjacent areas could still be a source of flammable or combustible material. Ventilating an area in this case would simply keep drawing in other ignitable mixtures rather than capturing a local release so designing a failsafe ventilation system in these circumstances is probably not feasible.

However, most research applications — not all but most — usually are small enough in size and area and limited enough in the quantity of flammable or combustible materials that providing ventilation designed to capture any releases at the local source and keeping the ignitable area to a negligible extent is feasible. Hence, API 500 does not prohibit using ventilation as a mitigative measure in many research applications. It, for example, specifically excludes laboratories in 6.3.1.2.3 due to the nature of their operations and their high ventilation rates.

NFPA 497 is clearer on this point, noting in 5.5.1 that:

Experience has shown that the release of ignitible mixtures from

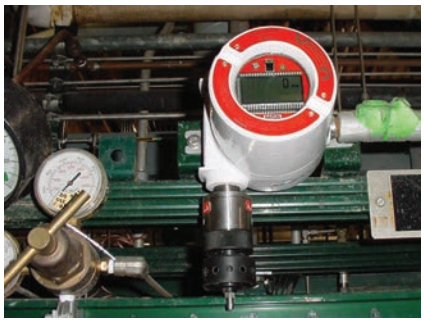

FIGURE 3. Fixed gas detectors can be an important mitigation measure

some operations and apparatus is so infrequent that area classification is not necessary. For example, it is not usually necessary to classify the following locations where combustible materials are processed, stored, or handled:
(1) Locations that have adequate ventilation, where combustible materials are contained within suitable, well maintained, closed piping systems
(2) Locations that lack adequate ventilation, but where piping systems are without valves, fittings, flanges and similar accessories that may be prone to leaks
(3) Locations where combustible materials are stored in suitable containers
(4) Locations where the use of combustible liquids, or flammable liquids or gases, will not produce gas or vapor sufficient to reach 25 percent of the lower flammable limit (LFL) of that combustible material

A very important concept if one chooses to use ventilation as a mitigative measure is keeping the ignitable area to a negligible extent. ISA 12.24.01 Recommended Practice for Classification of Locations for Electrical Installations Classified as Class I, Zone 0, Zone 1, or Zone 2 gave excellent guidance in this regard in 5.3:

The most important factor is that the degree or amount of ventilation is directly related to the types of sources of release and their corresponding release rates. This is irrespective of the type of ventilation, whether it be wind speed or the number of air changes per time unit. Thus, optimal ventilation conditions in the hazardous area can be achieved, and the higher the amount of ventilation in respect of the possible release rates, the smaller will be the extent of the zones (hazardous areas), in some cases reducing them to a negligible extent (nonhazardous area).

If you can design and install a ventilation system so that it will capture all the flammable or combustible material effectively at the source, then you should not need to classify an area.

Consider an open drum full of flammable material. For some distance above the drum, an ignitable mixture of flammable vapor and air (that is, a mixture over the LEL) is present. Classifying this area in lieu of other preventive measures is only prudent. Alternately, if one were to install a properly designed ventilation system that drew off these vapors immediately at the surface of the drum then the extent of this ignitable area would be very small; in the code language a "negligible extent". Suppose the design is effective in capturing all the vapors within one inch off the top of the drum. Does classifying the area several feet above the top of the drum and off to the side make any sense? At worst one might consider this one inch area above the drum as Class I Division 1 but then classify the rest of the area as unclassified. (And prudently don't put any electrical devices or wiring in that one inch.)

Ventilation as a mitigative measure requires careful design, proper installation and testing to confirm it is effective, regular maintenance to keep it working properly, and appropriate failsafe alarms and safeguards to warn of its failure and take the proper actions to keep the area safe. All these are required. They also cost and require routine attention.

Simply doing a calculation that indicates that the ventilation rate will dilute the flammable or combustible material below its LEL is not enough for many reasons. First, the larger the area within the explosive range, the higher the change of encountering an ignition source before dispersion. So, there is a real need to design a system to keep this extent small, approaching negligible.

Second, theoretical gas dispersions doe not approach real world conditions. American Conference of Governmental Industrial Hygienists' (ACGIH) "Industrial Ventilation, A Manual of Recommended Practice for Design" suggests a mixing factor to account for imperfect mixing that ranges from 1 to 10. Other sources suggest a similar safety factor of 2 to 5. Regardless of what value is used, the key point to recognize is that theoretical calculations rarely approach real-world conditions. Even computational fluid dynamics (CFD) simulations will invariably prove to be less accurate than expected.

Third, pressurized leak sources travel significantly longer distances. API 500 in Table 1 suggests an adjustment factor of 1.5 for pressures above 741 psig and 2.5 for pressures above 1,440 psig. Gas leaks will stay concentrated for significant distances before slowing and beginning to disperse. Finally, all ventilation calculations require you to assume a maximum leak rate. This is an area fraught with risk as too many things affect the size of a leak. Hence it can often be much larger or in a different place than expected.

The only truly safe approach is to either enclose the potential source of the release and ventilate it above the maximum possible leak rate one can credibly determine or provide a large enough system, properly designed, to capture the leak effectively at the source. In both cases, by moving the ventilation close to the source, one keeps the area of concern negligible. Prohibiting electrical equipment and wiring in this limited area is usually very feasible.

Gas monitoring. A third potential mitigative measure is continuous fixed gas detection (Figure 3). NFPA 70 in 500.7 states "*A combustible gas detection system shall be permitted as a means of protection in industrial establishments with restricted public access and where the conditions of maintenance and supervision ensure that only qualified persons service the installation.*" However, it limits use of a gas detection system to three specific cases:

- *A location that would be Class I Division 2 based on a hazard analysis and risk assessment except for inadequate ventilation can, with a fixed gas detection system, be considered Division 2.*
- *A building that would not be classified but is, wholly or partially, inside a Division 2 area can, with a fixed gas detection system, be considered unclassified.*
- *The interior of a control cabinet inside a Class 1 Division 1 area can,*

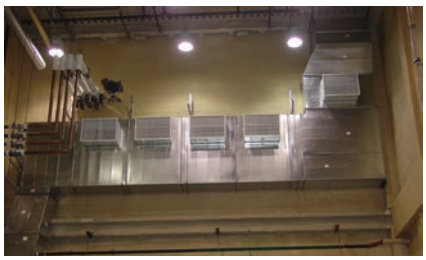

FIGURE 4. Adequate ventilation is important. Shown here is high-point exhaust in a pilot plant area

can, with a fixed gas detection system, be considered Division 2.

API 500 in section 8.2.8.2.4 goes further after allowing these same three cases and says:

All buildings and rooms that are determined to be adequately ventilated as per the requirements of 6.3 by mechanical means with a minimum of six (6) air changes per hour, and provided with gas detection meeting all of the requirements of 6.5 may be unclassified.

The logic is that the provision of two mitigative measures — adequate ventilation (Figure 4) and a fixed gas detection system — are adequate for safety, and area electrical classification is not required.

Again, these systems need to be properly designed, selected, and installed in a failsafe manner. They require both initial and ongoing routine calibration. They must be designed to work with all the gases that may be present and all the other compounds in the area that may inhibit proper sensing (poisons). Finally, an adequate number of sensors, properly placed to detect any release in a timely manner is required. These factors, particularly determining the last properly, make use of a gas detection system more challenging and, in many installations, highly problematic. Leaks can occur in locations not envisioned and far away from any sensor. Gas dispersion patterns may be very different from what is expected due to pressure, ventilation, open doors, obstacles, and many other factors. Hence selecting and placing the required number of sensors is always more uncertain. For research applications that are smaller and more limited in potential leak locations providing a larger number of sensors and placing them properly is still often possible.

In summary, area electrical classification is a powerful tool for process safety. Research applications should always evaluate its effectiveness, appropriateness, and mitigation. It is not, however, the only viable approach to a safe process. ■

Edited by Gerald Ondrey

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Economic Indicators

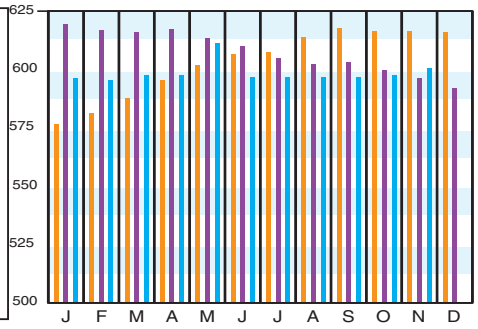
2018 2019 2020

Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	Nov. '20 Prelim.	Oct. '20 Final	Nov. '19 Final
CE Index	600.6	595.9	596.0
Equipment	728.2	720.7	723.3
Heat exchangers & tanks	615.0	607.7	619.9
Process machinery	724.5	720.9	720.7
Pipe, valves & fittings	979.2	965.1	955.9
Process instruments	423.2	421.0	419.2
Pumps & compressors	1084.0	1084.0	1072.8
Electrical equipment	569.5	568.9	561.6
Structural supports & misc.	768.5	755.1	764.6
Construction labor	337.4	337.7	336.0
Buildings	612.9	616.7	586.6
Engineering & supervision	310.8	310.9	313.3

Annual Index:
2012 = 584.6
2013 = 567.3
2014 = 576.1
2015 = 556.8
2016 = 541.7
2017 = 567.5
2018 = 603.1
2019 = 607.5



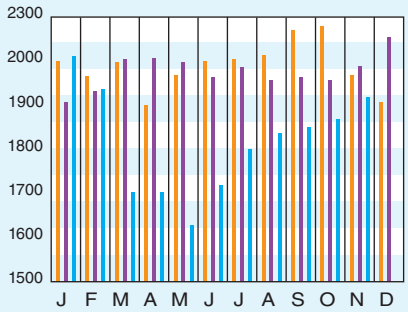
Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)

CURRENT BUSINESS INDICATORS

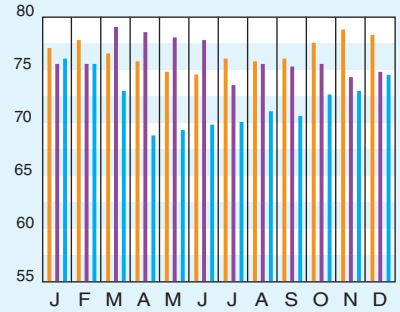
	LATEST	PREVIOUS		YEAR AGO
CPI output index (2012 = 100)	Dec. '20 = 99.6	Nov. '20 = 97.9	Oct. '20 = 98.0	Dec. '19 = 102.4
CPI value of output, $ billions	Nov. '20 = 1,890.3	Oct. '20 = 1,860.7	Sept. '20 = 1,845.2	Nov. '19 = 2,027.9
CPI operating rate, %	Dec. '20 = 74.5	Nov. '20 = 73.2	Oct. '20 = 73.2	Dec. '19 = 76.1
Producer prices, industrial chemicals (1982 = 100)	Dec. '20 = 235.3	Nov. '20 = 228.4	Oct. '20 = 226.5	Dec. '19 = 246.9
Industrial Production in Manufacturing (2012 =100)*	Dec. '20 = 102.2	Nov. '20 = 101.3	Oct. '20 = 100.5	Dec. '19 = 105.1
Hourly earnings index, chemical & allied products (1992 = 100)	Dec. '20 = 195.5	Nov. '20 = 191.9	Oct. '20 = 188.6	Dec. '19 = 187.9
Productivity index, chemicals & allied products (1992 = 100)	Dec. '20 = 102.7	Nov. '20 = 102.3	Oct. '20 = 100.8	Dec. '19 = 98.2

CPI OUTPUT INDEX (2000 = 100)†

CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2000 to 2012
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the *CE* Plant Cost Index (CEPCI; top) for November 2020 (the most recent available) increased compared to the previous month's value. The increase for November is the second consecutive monthly increase, and this month's rise is larger in magnitude than the previous month's increase. An uptick in the Equipment subindex in the latest data drove the overall monthly increase in the CEPCI, offsetting small decreases in the Construction Labor, Buildings, and Engineering & Supervision subindexes. The current CEPCI value now sits at 0.8% higher than the corresponding value from November 2019. Prior to this month, the year-over-year value for the CEPCI had been negative since July 2019.